WORLD ANIMAL REVIEW

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A QUARTERLY JOURNAL DEVOTED TO WORLD DEVELOPMENTS IN ANIMAL PRODUCTION, ANIMAL HEALTH AND ANIMAL PRODUCTS

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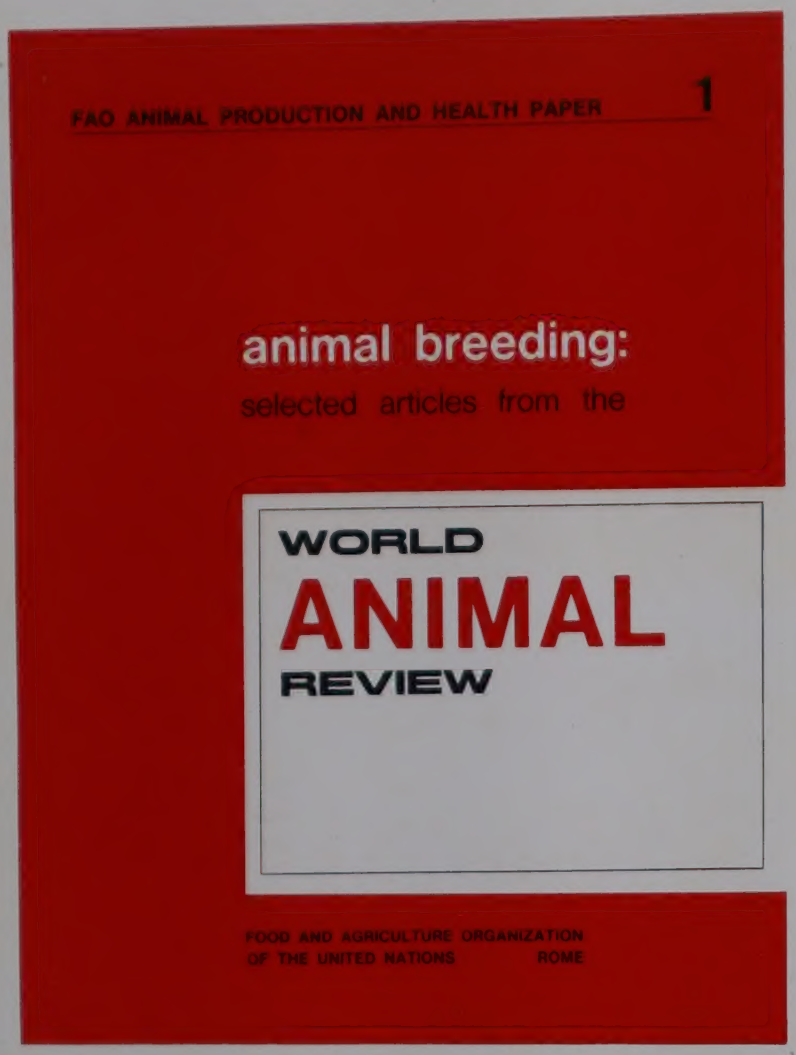

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FAO Animal Production and Health Paper No. 1 is a volume containing articles on animal breeding published in the first twenty issues of the *World Animal Review*. It presents the experience and the results of the work of animal breeders and geneticists from sixteen countries. Although the main focus of the articles is on animal breeding in developing areas of the world, information from developed countries is also included. The publication is designed to provide a ready and easy reference to those concerned with the improvement of milk and meat production, particularly in the warmer areas of the world.

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COVER: Afghanistan. Extension and training programme for breed improvement of Karakul lambs. (See article, page 2)

Photography by F. Botts, FAO

Animal production in the veterinary curriculum

J. Rendel

In his practical work with farm animals and in various governmental functions, the veterinarian will continually be faced with problems and questions which require a good understanding of practical animal husbandry and animal nutrition and breeding. The veterinary curriculum should therefore comprise animal husbandry subjects in addition to the basic sciences and para-clinical and clinical subjects. However, animal husbandry is also generally taught as a part of the agricultural curriculum for university students taking degrees in agriculture.

The content of the animal husbandry courses in the two curricula is usually different — and where this is not so, a differentiation ought to be considered. The degree course in agriculture usually pays more attention to the interrelationship between animal husbandry and crop production and the economics of various production and management systems, while in the veterinary curriculum animal husbandry teaching aims mainly at disease prevention. In spite of this difference in emphasis, there is usually considerable overlap, so that cooperation between the two programmes can increase efficiency and decrease the overall cost of training. This article discusses the type of animal husbandry training that future veterinarians will require and possible institutional arrangements for such training.

The author is Chief of the Livestock Research and Education Service in FAO's Animal Production and Health Division. This article is based on a paper presented at the First National Veterinary Conference in Benghazi, Libya, in October 1977.

Role of the veterinarian in animal production. The main task of the veterinary profession is to ensure that farm animal populations are reasonably healthy, that epizootic diseases and zoonoses are under control, and that animal products and food in general offered to the consumer are hygienic and wholesome. In the industrialized countries the veterinarian is also to a large extent engaged in the treatment and care of pets and animals used for sporting purposes; he also plays an increasing role in biological research in general. The proportion of veterinary manpower engaged in the above activities varies considerably between countries.

The approach to disease control and prevention differs greatly between developed and developing countries. In western Europe, for instance, one of the main functions of the veterinarian is to work in large-animal practice concerned with the care, control and prevention of disease in individual animals. In the developing countries, on the other hand, there are very few private practitioners; the number of veterinarians is small, and most of them are government employees. Disease control is carried out through governmental health schemes, and where there are animal clinics to serve the public the peasants usually bring their animals to the clinic.

In spite of the small number of veterinarians in the developing countries, quite impressive results have been achieved in the control of diseases characterized by high mortality such as rinderpest, anthrax and contagious bovine pleuropneumonia. The improved disease situation has paved the way for investments in more intensive animal production systems. Almost all developing countries are now making efforts of various kinds to improve animal production through intensification. The most striking examples are the many governmental and cooperative schemes for dairy production using temperate or cross-bred cattle and the many large-scale poultry units. However, the progress of many of these schemes is hampered at all levels by a serious lack of manpower trained in practical animal husbandry.

During the colonial era in Africa and Asia practically all animal production was under the care of the veterinary services, as there was a need to concentrate on disease control. Crop production was the responsibility of the agricultural services which were staffed by agriculturists with little or no training in animal husbandry. When the demand for more intensive animal production methods started to arise, there was a vacuum in many developing countries with regard to knowledge and skill in animal husbandry techniques, a vacuum which is now being gradually filled through the efforts of both veterinarians and graduates in agriculture. Since these two groups of professionals enter the field of animal production with very different back-

grounds, there is often a feeling of competition between them. Such feelings are human but should not be overemphasized, the task to improve animal production techniques in the developing countries being so enormous that there is a role for everyone interested in participating.

In the long term, it is likely that, as in Europe and North America, a pattern will emerge whereby the veterinarians will concentrate on the disease prevention aspects of animal husbandry, while the agricultural graduates will concern themselves more with the development of economic production techniques. However, for some time to come, it is inevitable that the veterinarians in the developing countries will be relatively more involved in animal husbandry extension and research than their colleagues in Europe and North America. In some countries, particularly those in Asia and the Far East, there is a strong desire on the part of the veterinarians to maintain an overriding influence on animal husbandry development. This aspect will be considered later in the section on the training of veterinarians in these countries.

Animal husbandry in the veterinary curriculum. The composition of the veterinary curriculum has been subject to consideration and discussion at several international meetings. The FAO/WHO Expert Panel (1963) and the FAO/WHO International Meeting (1965) on veterinary education studied the matter in detail and made a number of recommendations as to the duration and content of the course leading to a degree in veterinary medicine. It was agreed that the basic veterinary course should have a minimum duration of four years and that it should be preceded by pre-veterinary studies of at least one year. The pre-veterinary courses would aim at giving the students a sufficient knowledge of the basic natural sciences (mathematics, physics and chemistry), biological sciences (zoology and genetics) and languages. In the United States such pre-veterinary studies must have been completed before the student is admitted to a veterinary school; a minimum of two years' study toward a B.S. degree is usually required. In the European countries, pre-veterinary studies are usually arranged by the veterinary school and commence after the student has been admitted to the school.

The composition of the basic four-year veterinary course recommended by the FAO/WHO Expert Panel on Veterinary Education is given in Table 1. The total number of hours amounts to about 4 000 and the proportion allotted to animal husbandry is recommended to vary between 11 and 18 percent. It was agreed that in developing countries more time and attention to animal husbandry would be needed than in the industrialized countries. The extra time for animal husbandry would have to be taken from the clinical subjects; for instance, small-animal clinical work and surgery can, at present, be given less priority in most developing countries.

The components of the animal husbandry course for veterinarians would receive a different emphasis from that for animal husbandry students from an agricultural faculty. Animal nutrition and feeding are undoubtedly of prime importance to animal health; animal husbandry teaching for veterinarians should therefore comprise a solid course in these subject-matter areas. Through courses in animal physiology and biochemistry veterinary students would have received a good basis for the understanding of animal nutrition theory. However, they will also require teaching and training in practical animal feeding and in feeding systems based on feed resources available in their home countries. Another area of great importance to the future veterinarian is animal management and housing; these are

Afghanistan: photographing Karakul lamb as part of the selection process

factors that influence both the health of the animals and the human environment.

Animal breeding, pasture management and the economics of different production and management systems are also of great importance but will have to be given less attention within the overall time available in the veterinary course. For a good understanding of the selection theory of animal breeding a thorough knowledge of statistics is required, but there is not sufficient time for this. Similarly, the time that can be devoted to botany and agronomy or economic theory is not enough for complete courses in pasture and forage production or in agricultural economics. Veterinary students should therefore only be given orientation courses in breeding, pasture and forage production, and livestock production economics.

It is the wish of some countries, particularly in Asia and the Far East, that veterinarians should become more involved in agricultural extension and rural development (FAO, 1976). In these situations they would have to follow courses in such subjects as rural sociology, extension techniques and agronomy. However, in order not to prolong unduly the general veterinary course, it would seem advisable to let veterinarians entering the extension services take these courses after having obtained the basic degree. These extra courses can then be followed in the faculties where they are usually given (i.e., in schools of agriculture or rural science).

INSTITUTIONAL ARRANGEMENTS FOR TEACHING AND RESEARCH IN ANIMAL HUSBANDRY

Veterinary schools in central northern and northwestern Europe usually started as independent teaching units without any connection with universities, medical faculties or schools of agriculture. In the United Kingdom it was not until shortly after World War II that all of the veterinary schools were brought under the control of the universities; on the European continent and in Scandinavia several of the veterinary schools are still independent colleges without administrative connections with the universities.

The organization of a veterinary school as an independent unit located at a different site from a university has many shortcomings. Veterinary students cannot benefit from daily contact with students from other faculties; research contacts with colleagues in related fields are hampered; and cost per student is likely to increase because sharing of teaching facilities and staff cannot be arranged between faculties. Where new veterinary schools have been established, they are therefore almost always made component parts of traditional universities or of agricultural universities.

The cost of training veterinarians is usually higher than the training of other professionals, and cost efficiency has therefore to be given great attention. The cost of training in veterinary and other faculties was compared in a recent British study, some of the pertinent results being summarized in Table 2. The unit cost (the total current expenditure of the faculty divided by the total student number) was more than five times higher for veterinary science training than for social sciences; it was even considerably higher than for human medicine. The situation in the United Kingdom is probably fairly representative of the situation in general. Planners of new veterinary schools must not therefore limit themselves to looking into possible arrangements which will give high efficiency and quality of teaching and research; they must also consider cost efficiency.

TABLE 1. **Recommended composition of the general veterinary course**

Subject	Hours	Percent
Anatomy	570	14
Physiology	450	11
Animal husbandry Genetics and breeding Management and housing Nutrition and feeding Forage and pasture Livestock economics	430-700	11-18
Pathology	810	20
Public health and food hygiene	120	3
Pharmacology	120	3
Clinical studies Medicine Surgery Reproduction	1 230-1 500	31-38
Total	4 000	100

Source: FAO, 1965.

TABLE 2. **Unit costs of veterinary and other faculties in the United Kingdom, 1971-72** [1]

Subject group	Recurrent unit cost £St.	Relative [2]
Social studies	398	1.00
Pre-clinical medicine and dentistry	1 097	2.75
Clinical medicine	1 598	4.15
Engineering	911	2.28
Agriculture	977	2.45
Veterinary sciences	2 124	5.31
Biological sciences	1 013	2.54
Physical sciences	1 054	2.64

Source: The committee of inquiry into the veterinary profession, 1975.

[1] Represents total expenditure (academic and other salaries, consumables, purchases of equipment and other expenditure) divided by total student (undergraduate and postgraduate) load. — [2] Social studies taken as 1.

Subject-matter relationships to other faculties. When planning new veterinary schools, it is important to consider the relationships of the veterinary course to that of other professional courses, and how departments in various schools may cooperate to obtain high-quality teaching and research at reasonable costs. Many of the major subjects in the veterinary course bear a close relationship to subjects also being taught in faculties of human medicine, science and agriculture. In the case of the pre-veterinary subjects all these are dealt with in considerable depth in other faculties. Therefore, courses in these subjects suitable for

the future veterinarian could very well be arranged outside the veterinary schools.

The courses in basic physiology and biochemistry required by medical students, future veterinarians and students of animal husbandry in agricultural faculties are almost identical. From the cost efficiency point of view consideration should therefore be given to the possibilities of having a joint department serving all three faculties. But this is complicated by the fact that courses will be required also in special physiology, and in this respect there is very little overlap between the veterinary and the human medicine courses as the latter will not deal with subjects like ruminant or avian physiology. But there would still be some overlap with the special physiology courses for animal husbandry students in schools of agriculture. However, veterinary students often take a more substantive course in physiology than animal husbandry/agricultural students. The optimum solution may therefore involve the formation of one large department of physiology and biochemistry offering one basic course common to a number of faculties and also specialized courses for different streams of students. As this would imply the formation of a very large department as well as co-operation between several faculties, such a solution may be difficult to arrange. A more realistic approach would therefore be a department of physiology and biochemistry placed in a veterinary faculty and serving both the agricultural/animal husbandry and veterinary students.

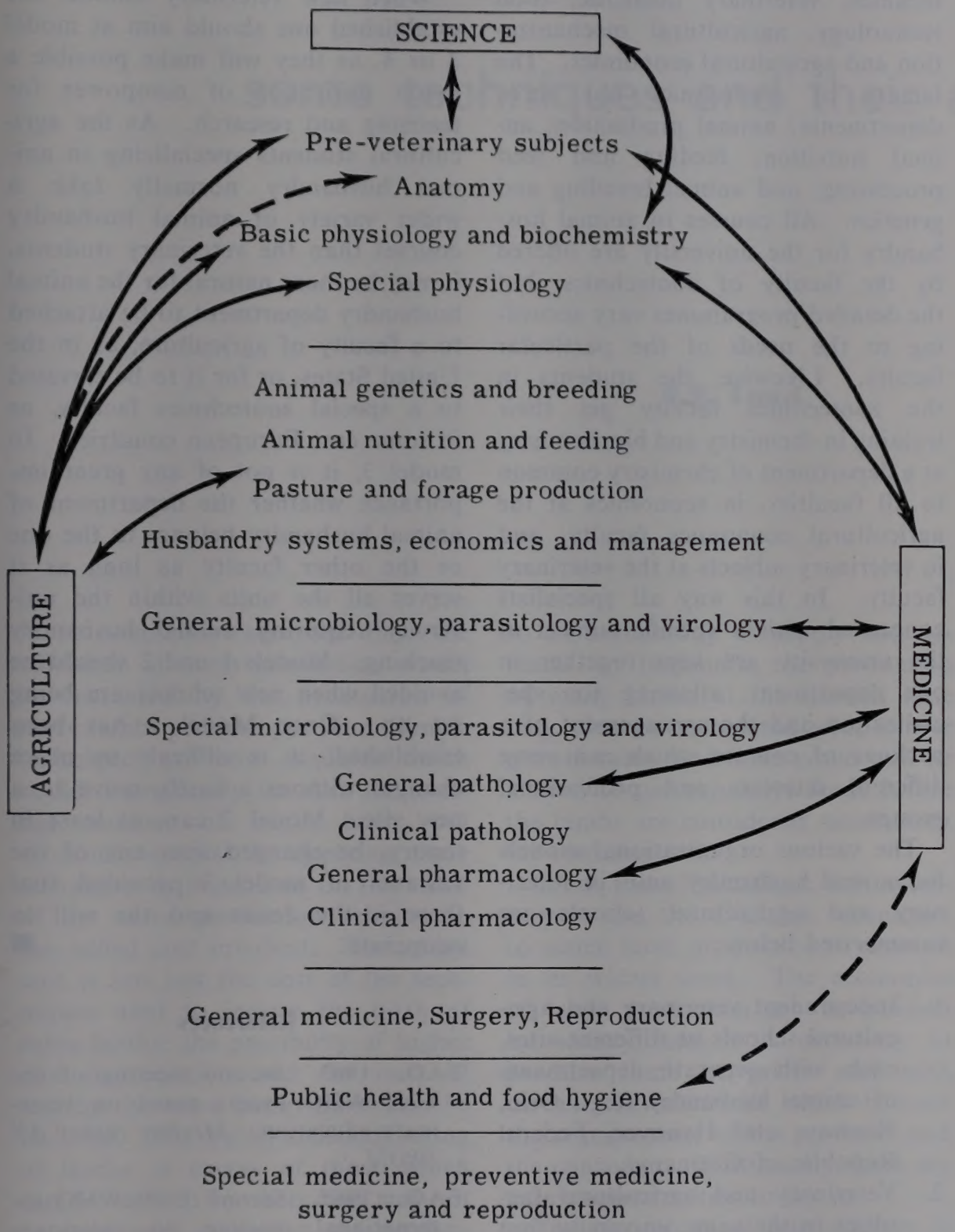

FIGURE 1. Interrelationships between the veterinary curriculum and other professional faculties.

It would fall outside the scope of this article to discuss all the possible ways in which cooperation could take place between the veterinary course and other professional courses in the general run of universities or in agricultural universities (an outline of the interrelationships is given in Figure 1). The main concern here is how cooperation between veterinary and agricultural schools may be best arranged in teaching and research in animal husbandry.

In those veterinary schools which are administratively independent of other university faculties or university-level agricultural schools there is very little possibility for integration of animal husbandry teaching and research with other institutions. In these veterinary schools there has to be a department or departments dealing with animal husbandry matters, and as the subject is very comprehensive, there is usually a need for at least three professors or senior lecturers: one for nutrition, one for breeding and genetics, and one for management and housing. Small schools are expensive to run, and the teachers will have to do their research in some degree of isolation. This system still exists in several veterinary schools in central and northern Europe. The schools are often well established, and for many reasons a change of location is difficult to make. However, the same system often exists also where veterinary training is offered within universities having both faculties of agriculture and veterinary medicine. In these cases it is difficult to understand why partial or complete integration of the departments of ani-

mal husbandry in the two faculties has not taken place, as this would certainly lead to more efficient utilization of available resources. The environment for animal husbandry research would most likely also be improved.

Possible organizational models. Various options and models for integration can be practised. In the United States almost all animal husbandry teaching for veterinary students is taking place in departments of animal husbandry within faculties of agriculture. On the other hand, such orientation courses in animal health matters that the agricultural students may need are organized by the veterinary faculties.

In some cases different approaches to the organization of animal husbandry teaching are used even within the same country. At the University of Melbourne, Australia, for example, there is only one department of animal husbandry, which is located at the School of Agriculture but serves the veterinary school as well. At Sydney University, however, a large and diversified animal husbandry department is located in the veterinary faculty. Many optional courses are offered, some of which are taken by the veterinary students, some by the agriculturists and some by both. At the University of Nairobi, Kenya, the animal husbandry department is located in the veterinary faculty; however, contrary to the situation in many other countries the veterinary and agricultural students are offered exactly the same course. There may be valid reasons for this, but in the author's view a differentiation is preferable. At the University of Ibadan, Nigeria, the department of animal husbandry belongs to the faculty of agriculture and serves both this faculty and the veterinary faculty. This department is probably the largest and most diversified animal husbandry department in Africa north of the Zambezi river. It offers different courses to veterinary students and to animal husbandry students of the agricultural faculty.

Many more examples of institutional arrangements are available, but one particularly worthy of note is the establishment of special zootechnical faculties within agricultural universities, an approach widely used in eastern Europe. At the Agricultural University of Warsaw there are separate faculties of agriculture, zootechnics, veterinary medicine, food technology, agricultural mechanization and agricultural economics. The faculty of zootechnics has three departments: animal production; animal nutrition, feeding and feed processing; and animal breeding and genetics. All courses in animal husbandry for the university are offered by the faculty of zootechnics, but the detailed programmes vary according to the needs of the particular faculty. Likewise, the students in the zootechnics faculty get their training in chemistry and biochemistry at a department of chemistry common to all faculties, in economics at the agricultural economics faculty, and in veterinary subjects at the veterinary faculty. In this way all specialists concerned with a specific subject at the university are kept together in one department, allowing for specialization and the arrangement of a package of courses which can serve different interests and professional groups.

The various organizational models for animal husbandry units in veterinary and agricultural schools are summarized below:

1. Independent veterinary and agricultural schools at different sites, each with separate departments of animal husbandry (e.g., Oslo, Norway, and Hanover, Federal Republic of Germany).
2. Veterinary and agricultural faculties in the same university, but with separate departments of animal husbandry (many countries).
3. Veterinary and agricultural faculties with a shared department of animal husbandry —
   (*a*) Department located in the agricultural faculty (e.g., Ibadan, Nigeria).
   (*b*) Department located in the veterinary faculty (e.g., Nairobi, Kenya).
   (*c*) Joint department responsible to both faculties.
4. Agricultural university with faculties of zootechnics, agriculture, veterinary medicine, agricultural economics, etc. (e.g., Warsaw, Poland).

When new veterinary schools are established one should aim at model 3 or 4, as they will make possible a better utilization of manpower for teaching and research. As the agricultural students specializing in animal husbandry normally take a wider variety of animal husbandry courses than the veterinary students, it may be more natural for the animal husbandry department to be attached to a faculty of agriculture, as in the United States, or for it to be elevated to a special zootechnics faculty, as in some east European countries. In model 3, it is not of any great importance whether the department of animal husbandry belongs to the one or the other faculty as long as it serves all the units within the university requiring animal husbandry teaching. Models 1 and 2 should be avoided when new schools are being set up. Once Model 1 has been established, it is difficult to make changes without a costly move to a new site. Model 2 can, at least in theory, be changed into any of the variants of model 3 provided that there is the desire and the will to cooperate. ■

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Increasing multiple births and frequency of lambings

some techniques and their application

R.B. Land

It is commonly accepted that the efficiency of lamb production would be increased by the production of more lambs per ewe per year. Simple techniques are now available which could dramatically increase the average number of lambs born, but economic success in applying these techniques is dependent on the value of the extra production relative to the added cost involved. The added cost is not just the cost of the techniques used to induce the birth of extra lambs; the possibility of higher ewe depreciation and the cost of rearing the extra lambs must also be included. The wholly artificial rearing of lambs in excess of those which can be suckled by their dam may not be economic; moreover, the production of lambs at a time of year when feed supplies are scarce, and therefore expensive, may also be disadvantageous. However, it should be noted that out-of-season lambing is not the only factor that could lead to an asynchrony of supply and demand for feedstuffs; the production of many lambs at the normal time may also be associated with slower growth rates, and there could well be a need to use expensive feeds before the lambs are considered satisfactory for consumption.

Given these limitations, it is necessary to use the available techniques to match lamb production to demand in its widest sense. The economics of lamb production are determined by society, and it is necessary to produce lamb at prices and with carcass characteristics which balance the requirements of the producer and the consumer. Fortunately there are many opportunities to do so.

The physiology of reproduction is now sufficiently well understood for reliable techniques to have been established to modify the reproductive performance of the sheep to suit society rather than the sheep. The reproduction of different types of sheep and genetic differences between them are being characterized, so that it is now possible to modify the reproductive performance of particular breeds in a predictable way by crossing. Improved methods of selection are becoming available. The nutritional requirements of lamb growth are now well enough understood for the costs of rearing to be minimized for a given set of needs and circumstances. Breeds with different growth characteristics can be used as sires to modify lamb growth to accommodate both the availability of feedstuffs and the requirements of the local market.

It is proposed to discuss physiological and genetic techniques in turn, and then to consider the ways in which they have been combined to improve lamb production.

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PHYSIOLOGICAL TECHNIQUES

Physiological manipulation of reproductive performance is based essentially on the following considerations. The number of lambs born is limited by the number of eggs shed; the number shed and the presence or absence of ovulation are in turn influenced by the balance between the stimulatory gonadotrophic hormones from the pituitary gland and

the feedback effects of ovarian steroids on their release; seasonal and lactational anoestrum are usually associated with both high concentrations of prolactin in peripheral plasma and inadequate gonadotrophic stimulation; progesterone prevents ovulation and is also necessary for oestrus as well as for pregnancy; the adrenal system is involved in parturition. Oestrus usually follows the consecutive presence of the steroids progesterone and oestrogen. Reproduction is affected by changes in day length; usually, sheep are reproductively active in the autumn and winter months, but quiescent in the spring and summer.

Some of the major pathways involved in the control of reproduction are summarized in Figure 1.

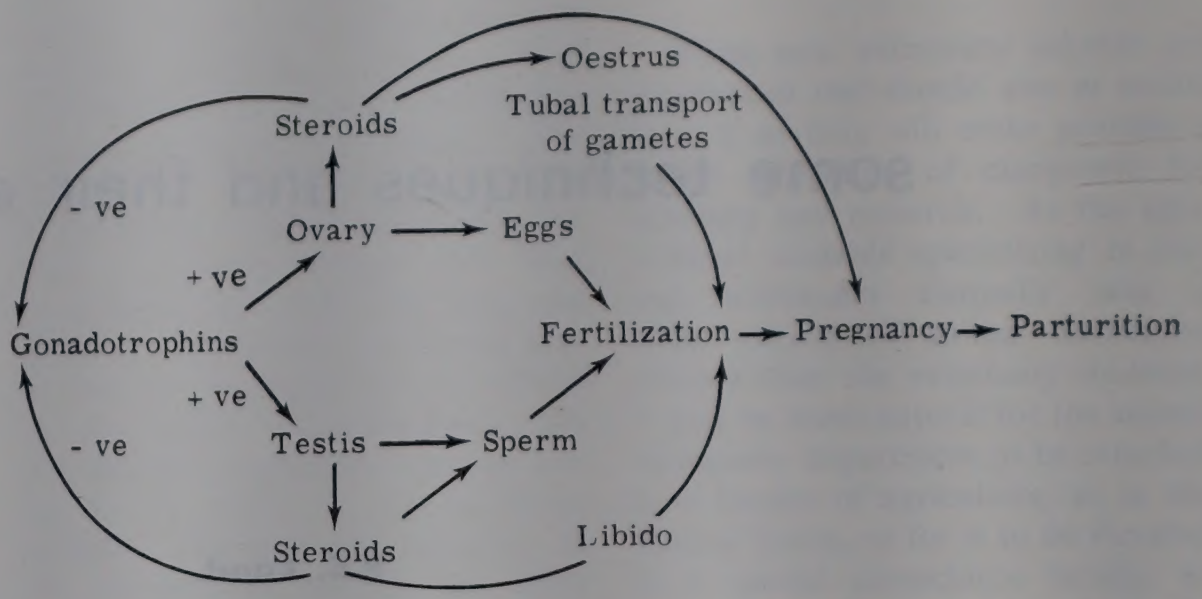


FIGURE 1. Summary of relationships between principal factors controlling reproduction.

Number of eggs shed. Artificial control of the number of eggs shed is dependent upon changing the natural balance between gonadotrophic stimulation and the feedback control of gonadotrophin release. Traditional attempts to increase the ovulation rate have been based on the use of exogenous gonadotrophins, largely as a result of the ready availability of pregnant mare's serum gonadotrophin (PMSG). That such treatment can increase the number of embryos present in different breeds of sheep is shown by the recovery of approximately twice the normal number of embryos (Bradford, Quirke and Hart, 1971). However, this procedure has two drawbacks. Firstly, the response is very variable, so that the twofold increase in embryo number is not translated into a twofold increase in litter size; some ewes have no embryos, while others may have so many that embryo mortality will increase. The second problem is that, when the number of developing follicles moves out of the normal range, the extra ovarian steroids produced affect sperm transport in the Fallopian tubes, leading to a failure of fertilization; thus, further increases in litter size are not possible. These drawbacks are not due to the placental origin of PMSG; exogenous pituitary gonadotrophins have similar effects. The net result is that PMSG is seldom used to increase the ovulation rate; it is, however, used to stimulate ovarian activity outside the normal breeding season, and this will be discussed later.

More recently, attemps have been made to modify the feedback control of gonadotrophin release, the philosophy being that, in general, only small increases in ovulation rate are required, and that the retention of the normal buffering system will avoid the increased variability resulting from the use of gonadotrophins. The use of anti-steroids such as clomiphene and active or passive immunization against steroids have been considered and show promise. Increases in the ovulation rate have not been associated with increases in variance, but these techniques have not yet been developed for practical application.

Synchronization of oestrus. Although it is not possible to change the number of eggs shed in a controlled manner, it is possible to affect the time of ovulation. Progesterone from the corpus luteum blocks ovulation but not follicular growth and development. The regression of the corpora lutea by prostaglandin $F_{2\alpha}$ from the non-pregnant uterus leads to a fall in plasma progesterone concentrations, oestrus and ovulation. The natural situation can therefore be manipulated either by giving exogenous progesterone, or by inducing the regression of the corpora lutea artificially by the injection of an analogue of the natural prostaglandin. Progesterone is usually given as a silastic subcutaneous implant containing, say, 375 mg progesterone (Abbot Labs.) or generated by a progestogen-impregnated intravaginal pessary (Searle or Upjohn). Prostaglandin (I.C.I. "Estrumate") can be given as an intramuscular injection of 50-100 μg.

To be successful exogenous progestogen must be given for long enough periods of time to effect synchronization, but not for so long that sperm transport is too badly affected; 12-14 days are usually considered satisfactory. Prostaglandin is only successful if there is a corpus luteum present, and for about 5 days around the time of ovulation this is not so. It is therefore necessary to give two injections, the first producing approximate synchronization so that all sheep have a corpus luteum present at the time of the second injection. Too long an interval between injections will not lead to synchronization, while too short an interval may lead to reduced fertility; the use of prostaglandin is still at the development stage.

Sheep would be expected to show oestrus two days after the withdrawal of progesterone, either directly following the removal of the source of exogenous hormone, or indirectly following the injection of prosta-

glandin and the regression of the corpus luteum.

Out-of-season breeding. Successful breeding either during lactation or out of season usually necessitates the induction of both oestrus and ovulation. In the absence of endogenous progesterone it is necessary either to provide it exogenously prior to the induction of ovulation, or to induce two successive ovulations so that progesterone from the corpora lutea of the first ovulation will prime the hypothalamus to respond to the oestrogen from the second. When the object is to synchronize oestrus, progesterone priming can conveniently be given in the form of a subcutaneous implant or an intravaginal sponge. Ovulation can be induced by the subcutaneous injection of PMSG (400-800 IU depending on the breed, nutrition, lactation and the stage of the season) up to 2 days before progesterone withdrawal (i.e., equivalent to day 13-15 of a normal oestrous cycle).

Although PMSG is more suitable for the induction of ovulation out of season than for the induction of superovulation, conception rates may not always be as high as during the breeding season, possibly depending on the "degree of seasonality" of a particular breed in a particular set of conditions. Gordon (1975), for example, reports a conception rate of only 35 percent in spring, whereas 95 percent of 45 Finn-Dorset ewes treated by Robinson, Fraser and McHattie (1975) conceived after mating at a similar time of the year (May); during the breeding season, the difference was much smaller (75 and 91 percent respectively). Alternative procedures are therefore being investigated. Some are based on the modification of the negative feedback from gonadal steroids as considered for the induction of higher ovulation rates, others on the use of hypothalamic releasing factors. The latter procedure, however, has not led to the establishment of a normal functional corpus luteum, possibly because of high prolactin levels during anoestrum; the combined use of releasing factors and drugs to reduce hypoprolactinaemia or to stimulate luteal function may be more successful.

Prostaglandins are only useful when a corpus luteum is present.

An artificial reduction in the duration of day length may also be used to induce out-of-season breeding. This is considered later.

Diagnosis of pregnancy. The presence of an embryo in the uterus prevents the regression of the corpus luteum of the oestrous cycle; progesterone concentrations remain high in peripheral plasma; and the corpus luteum is maintained through pregnancy. The presence of high concentrations of progesterone 15-18 days after mating is therefore diagnostic of pregnancy, and this can be detected in either peripheral plasma or milk by radioimmunoassay. Alternatively, ultrasonic equipment may be used to diagnose pregnancy instantaneously, and so the need to re-identify animals is avoided. Diagnosis may aid both intensive systems where oestrus is not normally checked and systems where mating is induced during anoestrus, because in the absence of further additional ovarian stimulation ewes which fail to conceive would not normally return to oestrus.

Induction of parturition. Variation in the time of lambing following synchronized mating is small enough to give the opportunity to synchronize lambing without the birth of "premature" lambs. The use of corticosteroids (Bosc, 1972) is relatively simple; 70 percent of females lambed over a period of 12 hours, with an average interval of 48 hours after the injection of 16 mg dexamethasone in the evening. The mean interval may be breed dependent. Alternatively, oestradiol benzoate (of the order of 15 mg IM) three days before the expected day of parturition can be used to synchronize lambing, 90 percent of ewes lambing in 48 hours; it may also have a beneficial effect on lactation (Terqui and Delouis, 1975).

Insemination. Sperm production, like ovarian activity, usually decreases during the period of the year when females are anoestrous. Libido would certainly be expected to drop. Further, synchronization of lambing during the breeding season poses an extra stress on insemination. Artificial insemination, using frozen or diluted semen, overcomes the demand for a large number of rams at a particular time, and overcomes low libido. The training of rams with oestrous females may maintain libido throughout "anoestrum." Induced ovulation need not be wholly synchronized.

Early weaning. Lactation may suppress cyclicity but not necessarily the prolificity of ewes which are cyclic. The removal of the lambs from the lactating ewe leads to an earlier resumption of cyclic activity, but with a growth check to the lambs. The suckling of two lambs has a greater adverse effect than one. These effects are direct effects, and cannot be relieved by improved nutrition; their magnitude, however, is breed-dependent, and may be affected by the environment, especially the photoperiod.

Lambs should be left with their mothers for two days to receive colostrum. Those removed at 2 days of age should be given "milk". Removal is inadvisable between 2 and 28 days of age, when lambs can be weaned but at the expense of reduced growth rates. Appropriate techniques and the balance between these variables are discussed in the following publications: *L'allaitement artifciel des agneaux et des chevreaux*, INRA, France; and *Artificial rearing of lambs*, Meat and Livestock Commission, U.K.

Artificial control of day length. In many instances the intensification of reproduction is accompanied by the provision of housing, which facilitates artificial control of the duration of the photoperiod. This may be achieved either by a reduction below the natural duration, or by a return to the natural duration following a previous period of supplementation. The choice is partly

dependent upon the time of year and the nature of the housing.

GENETIC TECHNIQUES

There are marked differences in reproductive performance between different breeds of sheep, and between individuals within breeds. This can be exploited to produce animals appropriate to a particular environment by selection and for use in purebreeding or crossbreeding programmes. Crossing offers the advantage of heterosis, the extent of which varies but could reasonably be expected to be about 5-10 percent. Techniques and opportunities for genetic improvement have been reviewed by Land (1977). The first step is the choice of the most suitable breed or cross; only then should within-population selection be considered.

Selection among breeds. The extent of variation among breeds is illustrated by the differences between the Finnish Landrace and the Tasmanian Merino breeds, the main characteristics of which are summarized below:

	Finnish Landrace	Tasmanian Merino
Onset of breeding in U.K.:	Mid-Oct.	Mid-Aug.
Age at first lambing (years)	1	2
Litter size	2.7	1.0

There is a similar difference between the crossbred offspring of these breeds, Finn × Blackface ewes producing 2.3 lambs per lambing compared to 1.2 lambs for Merino × Blackface.

It is possible to increase the number of lambs born by breed substitution or by crossing with breeds such as the Finnish Landrace or the Romanov, which have similar characteristics. This improvement is apparently not dependent on heterosis, and would be expected to be maintained in a "synthetic" population derived from F_1 matings, etc. The Chios has been specifically tried in the Near East by C.W. Fox and colleagues and has been found to raise the litter size of the Awassi by crossing. Another breed which offers considerable potential for crossing is the D'man of north Africa (Bouix and Kadiri, 1975).

Variation among breeds is not restricted to seasonality and the number of lambs born per lambing. Compared with the other breeds recorded, Finnish Landrace ewes have a shorter interval between lambing and the next fertile oestrus; 77 percent of purebred ewes, for example, become pregnant within 8 weeks of parturition while they are still suckling their lambs (the mean interval from parturition to conception is 6 weeks). This characteristic may be transmitted to the crossbred offspring; approximately 50 percent of Finnish Landrace × Dorset Horn ewes, for example, would be expected to conceive within 8 weeks of parturition while lactating. Crossing may also give rise to heterosis. Although this may on average be only of the order of 5 percent for each component of performance, the cumulative effect on overall production may be considerable: 20-25 percent (Nitter, 1978). In practice, however, the overall productivity of the best crossbreeding system relative to that of the best pure or "synthetic" breed is of more interest than the average effect over many breeds and crosses.

Selection within populations. It may be possible to improve performance by, say, 0.02 lamb per ewe per year, or 0.2 lamb in 10 years, through intense selection on litter size alone. Though basically a slow process, this may be aided and the rate of response increased by the use of male characteristics, the most promising of which is testis growth (Bindon and Piper, 1976).

PHYSIOLOGICAL AND GENETIC TECHNIQUES

Physiological. Techniques to improve the reproductive performance of the ewe are used more widely in France and Ireland than in other western European countries and the situations are described in "Maîtrise des cycles sexuels chez les ovins, état actuel et perspective", Searle, Paris; and by Gordon (1975) respectively. Ten percent of the sheep in France are inseminated following the use of vaginal sponges (Thimonier, J., 1977, personal communication). One consequence is the development of a technical infrastructure, where, for example, oestrus synchronization and artificial insemination of the sheep are conducted in the same way and sometimes by the same organizations as those providing an artificial insemination service for cattle.

Probably the ultimate example so far of the intensive control of a flock of sheep is that developed at the Service de la physiologie de la reproduction at Nouzilly, France, by J. Thimonier and his colleagues. Control is not only such that lambing takes place throughout the year, but work at weekends, at night and on public holidays is avoided. Progestogen sponges and PMS are used to synchronize and induce ovulation in non-cyclic females, while sponges alone are used for those cycling. Insemination is artificial, and the concentration of progesterone or oestrogen in peripheral plasma is taken to be diagnostic of pregnancy. Parturition is induced, and lamb rearing may be artificial. The system is summarized in Figure 2. Lambing takes place every 7 weeks, and lambed ewes are re-mated $7\frac{1}{2}$ weeks after lambing.

Although controlled physiologically, the productivity of this system is very dependent on the breed of sheep used. Thus, Romanov × Prealpe ewes produced 301 lambs per 100 ewes per year, compared to 223 lambs for Prealpe ewes, and only 181 lambs for Ile de France ewes (Thimonier and Cognie, 1977).

Genetic. Finn-Dorset sheep have been used at the Rowett Research Institute, U.K., to study the nutrition of sheep under intensive conditions; likewise, their genetics have been studied at the Animal Breeding Research Organization (ABRO). Both studies were designed to investigate

Finn-Dorset sheep at the Animal Research Organization, United Kingdom

rather than develop intensive systems, but they nevertheless indicate the potential productivity of Finn-Dorset sheep. The Rowett system involved the use of artificial control of day length, sponge synchronization of oestrus and PMSG, together with the early weaning of lambs at 4 weeks of age. It resulted in an average annual production of 3.3 lambs per ewe surviving per year (Robinson, Fraser and McHattie, 1975). Day length control has since been replaced by the use of 400 IU PMS during anoestrus; early results indicate that this procedure is equally successful (Robinson, Fraser and McHattie, 1978).

The ABRO system was simpler, the animals being run outdoors for part of the year and mating permitted in August and January-March. No physiological aids were used, and lactating ewes not mating within 56 days of lambing in the spring were not considered for mating until the following August. Despite these experimental restrictions, productivity was 2.9 lambs per ewe per year (Land and McClelland, 1971).

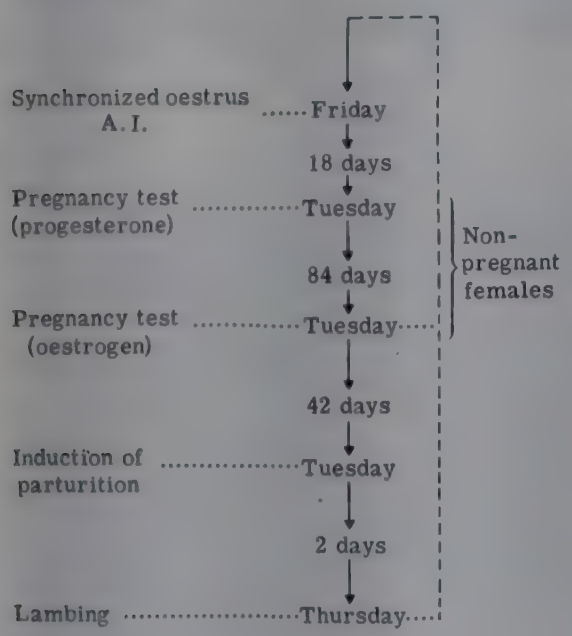
GENERAL CONSIDERATIONS

The merits of intensification are entirely dependent upon the availability and cost of resources relative to product. Finn-Dorset sheep, for example, lambing once per year in April and exploiting natural grazing, may produce 2.3 lambs per ewe per year with no "physiological aids" and very little supplementary feeding (Harris, J.C., personal communication). The provision of housing and the opportunity to mate within the first 8 weeks of lambing raise this to 2.9; the introduction of early weaning, oestrus synchronization and light control give a further increase to 3.3 lambs per ewe per year. The Ile de France, with all of the physiological inputs currently available, produces 1.8.

Thus, unless there is a special demand for a particular breed of sheep, it would seem inadvisable to introduce sophisticated techniques to sheep of low genetic merit for reproductive performance. This conclusion will be shown to be false if new pharmacological products are marketed which give a reliable increase in productivity, but the probability of this happening is likely to decline rather than to grow. Al-

though increased knowledge may make new drugs available, the cost of meeting new drug regulations is increasing, so that the economic incentive to the drug companies is declining. Genetic improvement may not only be the cheapest means of improvement; it may also be the only means available.

FIGURE 2. Outline of the pattern of controlled reproduction in the sheep flock of the INRA *Station de physiologie de la reproduction*, France.



The advantages to be gained by breed substitution or by crossing with breeds such as the Finnish Landrace and the Romanov have already been seen to be considerable; the same may also be true of the Chios and the D'man. The improvement in reproductive performance by such procedures may however be at the expense of a deterioration in other components of merit. Once the best breed or cross has been chosen for a particular environment, there are two alternative procedures for further improvement in overall merit. Selection can be conducted within the best population for each environment; or, if improvement in the same reproductive characteristics is required in several different environments, it may be advantageous to increase the merit of the crossing strain, which can then be used to improve the strains otherwise suited to particular environments. The proportion of the high merit strain to be introduced would be determined by the increase in reproductive performance required for a particular environment and its superiority over the strain to be improved. The higher the merit of the crossing strain, the lower the deterioration in other components of performance for a given improvement in reproductivity.

The introduction of schemes to intensify sheep reproduction depends on the costs of that intensification relative to the increased returns, and these may differ markedly between different countries. For any given set of conditions it is advisable to use the best genetic material; and as there may be an interaction in economic terms, the better genetic material itself may justify greater inputs. International cooperation may facilitate the evaluation of existing genetic resources, the improvement of particular breeds or strains, and the creation of strains with extreme merit to improve native breeds in a variety of environments.

The development of strains of high biological merit is particularly suitable for international initiative. Such strains could be made available wherever they were desirable, and would greatly increase the opportunities for rapid genetic change to meet demands of human societies.

International cooperation may also be harnessed to facilitate the introduction of new pharmaceutical products both through aid with biological investigation and through the standardization of legal requirements. Finally, it is of utmost importance to match the genotype and the husbandry system with the demands and attributes of the community. ■

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Improving the nutritive value of straw and other low-quality roughages by treatment with ammonia

F. Sundstøl, E. Coxworth and D.N. Mowat

Attempts to improve the nutritive value of straw and other low-quality roughages by chemical treatment have been made from about the end of the last century (Lehmann, 1895). The widest application of such treatment was probably reached in Norway where more than 1.5 million tons of straw have been treated according to the so-called Beckmann method since the Second World War. This method, based on wet treatment with sodium hydroxide, gives a high-quality feed, but owing to some serious disadvantages, of which the high water requirement and the pollution problems are predominant, the application has declined markedly since 1970. Today there is a worldwide search for new practical methods to treat low-quality roughages to increase their feeding value. One of the most promising is the ammoniation method. Anhydrous ammonia (NH_3, gaseous) and solutions of ammonia in water (NH_4OH, aqueous) have both shown a positive effect in improving the nutritive value of low-quality roughages. Many procedures for ammonia treatment have been described and others will probably be added in the future.

The Norwegian method. In Norway a method has been developed whereby straw is ammoniated in stacks covered with plastic. The method has been well accepted by the farmers, and in 1976 more than a thousand farmers applied this "stack method".

Because of the wide popularity that this method has gained in only two years since it was introduced, a brief description is given here (the principles are shown in Figure 1, *a-h*).

There are no specific requirements regarding the shape and size of the container in which the reaction between the material and the ammonia takes place. Most farmers use the "standard cut" 0.20-mm polyethylene, with the undersheet 6 × 6 m and the covering sheet 10 × 10 m. The stack should cover an area 4.6 × 4.6 m leaving a 0.7-m margin of plastic on each side for closure of the stack (see Figure 2).

The number of bales varies according to their size, it being easier to get a good stack if the bales are $1\frac{1}{2}$ or 2 times as long as they are wide. The stack is made about 2 m high, and six to eight bales are placed at the top, making a peak to enable the water to flow off when it rains. The alternative layers of bales should be stacked at right angles to each other to get the best possible binding of the stack. A lath should be placed between the third and fourth layers to provide an entrance for the injection pipe. The stack is covered with the 10 × 10-m top sheet leaving a free margin of 0.7-m plastic on each side, corresponding to that on the undersheet. It is important to adjust the amount of material in the stack to the size of the plastic because too little or too much plastic on the sides will make the sealing of the stack difficult. For maize stover a thicker plastic is probably necessary (e.g., 0.40 mm). Plastic which has been damaged in preceding treatments can be used under the airtight plastic to prevent puncturing. When the stack is completed, three sides are sealed by rolling the two edges of the under- and top sheets around a 4-m long wooden lath at the base of the stack (see Figure 3). It is then pinned down by sandbags placed at the top of the roll (see Figure 4). The fourth side remains unsealed until the ammonia has been injected.

The anhydrous ammonia is transported in pressure tanks on trucks and is injected through a perforated metal pipe which is put three quarters of the way into the stack (see Figure 5).

The application of ammonia should be carried out by specially trained personnel. They should also roll up and seal the last side of the stack as soon as the ammonia is added (see Figure 6). Ammonia is an unpleasant gas to handle, and one should remember that air containing 15-28 percent ammonia is explosive upon ignition. Although no accident is known so far, it is recommended that the stack should not be placed in or close to barns or other buildings.

Ammonia vaporizes quickly and spreads through the material. Kristensen, Busk and Danielsen (1977) have shown that the effect of ammonia on dry straw is much the same all over the stack. Immediately after injection of the ammonia the temperature in the upper part of the stack rises 30-40°C followed by a decrease to ambient temperature over the next 1-2 days. At the bottom, however, where the liquid anhydrous ammonia vaporizes, the temperature is initially very low (minus 20-30°C) and it may take several days before the temperature exceeds the freezing point

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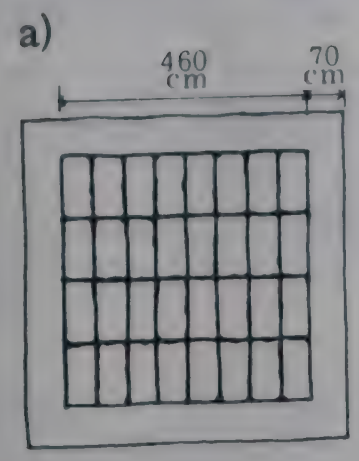
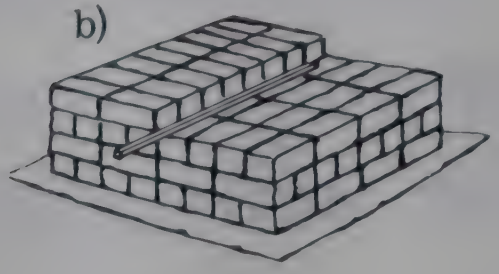




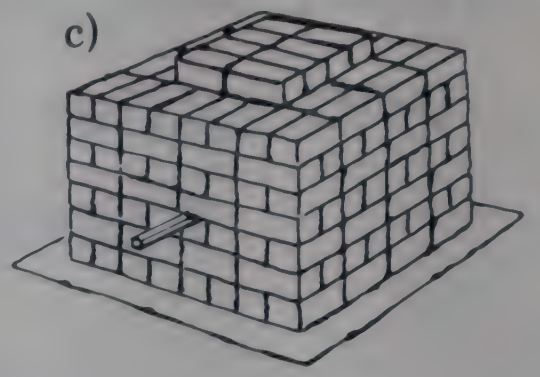
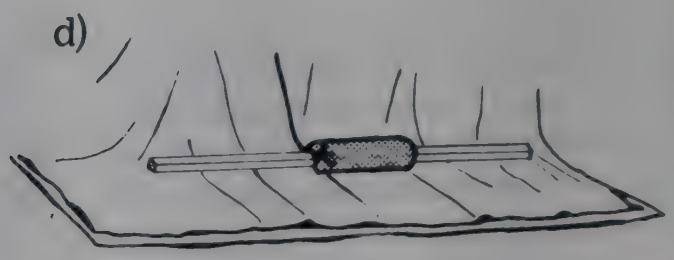
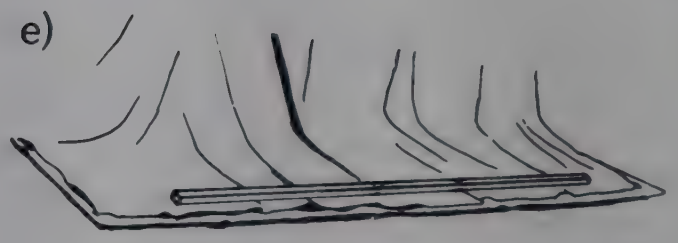


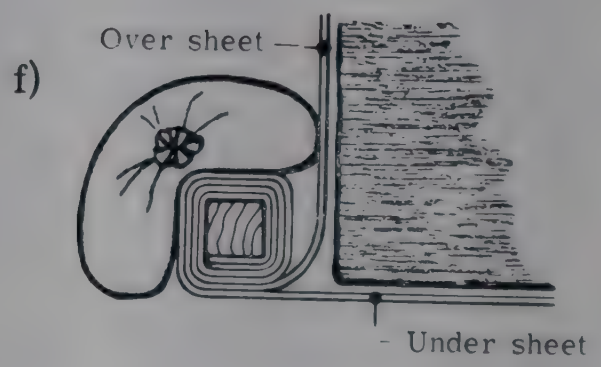
FIGURE 1. Principles of the "stack method" for ammonia treatment of straw (*a-h*).

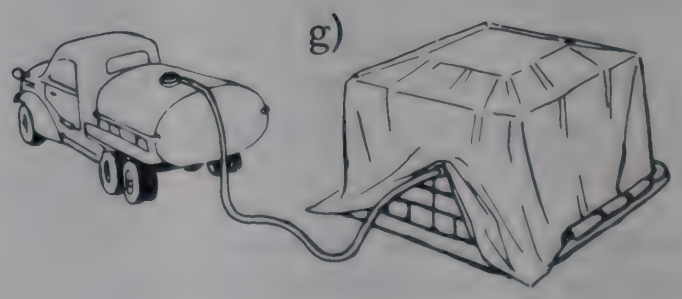
FIGURE 2 (above). The first floor of straw bales is completed (*a, b, c*).

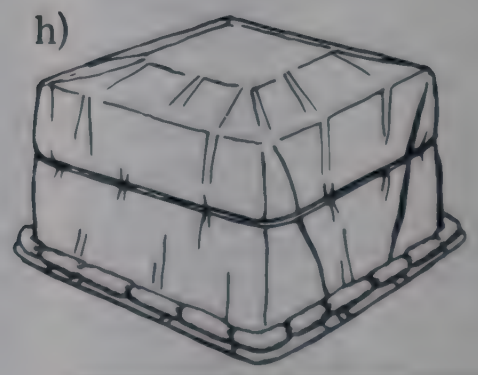
FIGURE 3 (below). Rolling the edges of the plastic sheets to seal the stack (*d, e*).











FIGURES 4, 5. Rolls fixed by sandbags (above); about 3% anhydrous ammonia is injected by perforated pipe (below).

FIGURE 6. Treatment time (weeks); depends on temperature

(±0°C). When the temperature outside the stack is low, moisture within the stack will condense on the inner side of the plastic. Water will then flow down the sides and cause an increasing moisture content in the bottom layer. According to Kristensen, Busk and Danielsen (1977), the digestibility (enzyme solubility) of this wet straw is considerably higher than that of the upper layers of the stack.

In Norway and Canada a treatment time of 4-8 weeks is generally advocated depending upon seasonal temperatures. In countries with a warmer environment this time can probably be reduced. When the stack is opened it should be left for at least 2 days (preferably 5 days) to allow the excess ammonia to disappear before transporting and feeding the straw. During ammoniation the straw changes from a yellow to a brownish colour, while the structure of the material is slightly softened.

The method described above should be taken as an example of how the ammoniation of low-quality roughages can be carried out at the farm level; a similar procedure is described by Kernan *et al.* (1977). Modifications of this method will of course be necessary to adapt to other conditions. For example, permanent containers for ammoniation of straw are already available on the market. By using such containers it is possible to add and to conserve heat, thus reducing the treatment time to a few days. Another way of utilizing the upgrading effect of ammonia on low-quality roughages is to combine it with physical treatment, e.g., grinding and pelleting, as is being done in the German Dem. Rep. (Bergner and Marienburg, 1971). Methods have also been developed based on ammonia released from urea by heat and pressure (Bergner, Zimmer and Münchow, 1974) and by the action of urease enzyme (Van der Merwe, 1976).

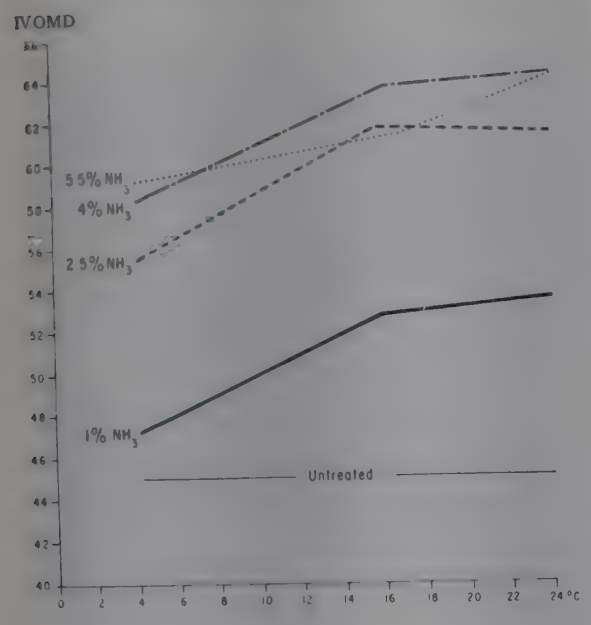
THE EFFECT OF AMMONIATION

Ammonia level: Most experiments indicate that there is very little im-

provement in digestibility resulting from an increase of the ammonia level above 3-4 percent of dry matter (DM). If ammonia is expensive, the economical optimum might lie even below 3 percent.

The effect of ammonia dosage on the *in vitro* digestibility of straw is illustrated in Figure 7. It shows a clear-cut effect of increasing the ammonia level from 1.0 to 2.5 percent, a lesser effect of a further 1.5 percent

FIGURE 7. The effect of varying NH_3 level in straw DM and treatment temperature on the **in vitro** digestibility of organic matter (IVOMD) in dry oat straw treated for 4 weeks.



increase, and no positive effect when ammonia was increased from 4.0 to 5.5 percent of straw DM. There was apparently no interaction between the ammonia level and treatment temperature.

Temperature: Ammonia is a slow-reacting chemical, but as with other chemical reactions the effect of ammoniation is accelerated by increasing temperature. Waagepetersen and Vestergaard Thomsen (1977) found that temperature had a positive effect up to 45°C with short treatment times (3 or 7 days). On the other hand, at very low temperatures (around or below the freezing point of water) the action of ammonia is very slow (F. Sundstøl, 1977 — unpublished data). There is however a significant interaction between treatment temperature and time. This means that low treatment temperature can be compensated for to a large extent by increasing the time of treatment (Figure 8).

Time of treatment is thus one of the important factors influencing the effect of ammoniation. In many of the early experiments with ammoniation of straw the treatment time applied was too short to obtain satisfactory improvements in nutritive value. For low-quality roughage treated with 3-4 percent ammonia at ambient temperature the following length of treatment may be recommended:

TEMPERATURE	LENGTH OF TREATMENT
Below 5°C	more than 8 weeks
5-15°C	4-8 weeks
15-30°C	1-4 weeks
Above 30°C	less than 1 week

Extending the treatment beyond the time indicated above would probably do no harm. The container (stack) should be kept sealed for as long as possible. In future it may be of interest to add heat or to conserve the heat produced during ammoniation so as to reduce the length of treatment.

Moisture content in the material influences the effect of ammoniation. Waiss *et al.* (1972) indicated that the optimum moisture content was 30 percent when rice straw was treated with 5 percent NH_3 at ambient tem-

FIGURE 8. The effect of treatment temperature and time on the **in vitro** organic matter digestibility (IVOMD) of oat straw containing 25% H_2O and treated with 3.4% NH_3 in DM.

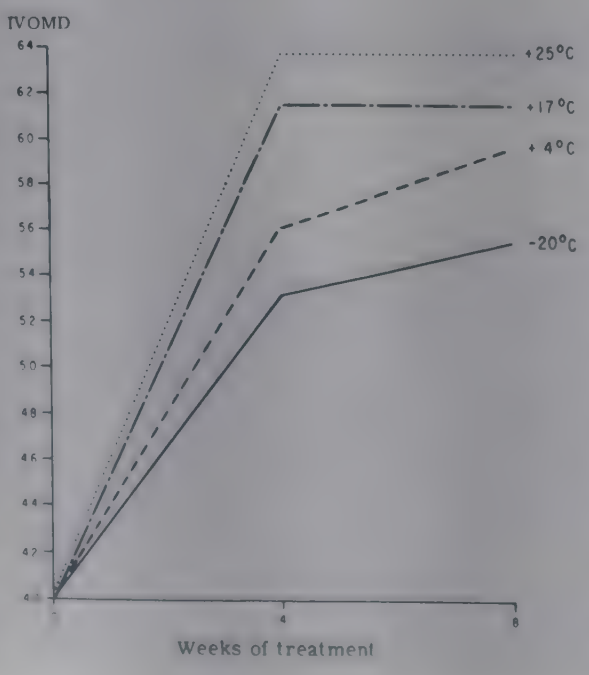
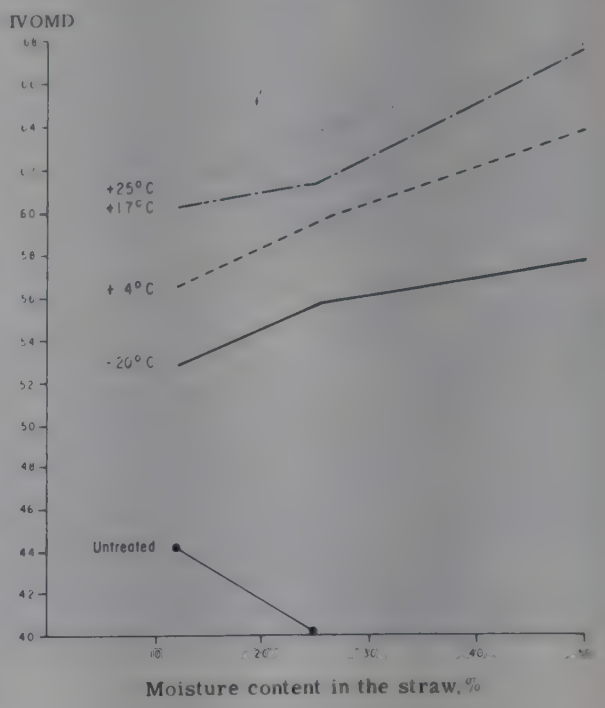


FIGURE 9. The effect of varying moisture content and treatment temperature on the **in vitro** organic matter digestibility (IVOMD) of straw treated with 3.4% NH_3 in DM for 8 weeks.



perature. More recent studies with oat straw have shown positive effects of increasing moisture content up to 50 percent (Figure 9). This is particularly true when a high NH_3 dosage (5-7 percent of straw DM) is applied. A high moisture content in the material may on the other hand cause some distribution problems when anhydrous ammonia is injected. If the material is to be dried, this should be done after rather than before the ammonia treatment.

Pressure is also a factor that might have some positive effect in ammonia treatment, but since high pressure is often combined with high temperature, it is difficult to distinguish between the effects of the two. For on-the-farm treatment high pressure is in most cases of minor interest and will not be discussed further in this article.

Initial quality and type of material may to a certain extent influence the effect of ammonia treatment. The experiments of Waiss *et al.* (1972) and Kernan *et al.* (1977) indicated that the improvement is somewhat more pronounced for untreated materials with a relatively low digestibility than for more digestible materials (Tables 1 and 2). The data of Kernan *et al.* (1977) also suggest that the crude fibre content of samples of a particular variety of straw is negatively correlated with the *in vitro*

digestibility of ammoniated as well as untreated straw. However, the effect of ammoniation was similar for high- and low-fibre straw. Digestibility trials with sheep by different investigators (Table 2) indicate that ammonia treatment seems to be effective for a wide range of materials. However, the response to alkali treatments is generally less for legume as opposed to grass forages. Many potential feed sources still remain to be tested.

TABLE 2. **Improvement in digestibility of crop residues as affected by ammoniation: sheep digestibility studies**

Crop residue	Treatment with NH_3	% dry matter digestibility (DMD)		
		Untreated	Treated	Δ DMD
Wheat straw [1]	5% anhydrous	36	50	14
Oat straw [1]	5% anhydrous	47	55	8
Barley straw [1]	5% anhydrous	43	55	12
Barley straw [2]	3.5% anhydrous (3 weeks)	47	60	13
Barley straw [2]	3.5% anhydrous (8 weeks)	47	64	17
Wheat straw [3]	1% (from decomposition of 2% urea added to the straw in a high-temperature pelleting process)	[4] 44	[4] 52	[4] 8
Rice straw [5]	5% aqueous	42	56	14
Maize stover [6]	5% aqueous	52	60	8
Maize stover [6]	3% aqueous	52	60	8
Maize plant (whole plants dehydrated) [7]	Not reported	57	69	12

[1] Coxworth **et al.** (1976). — [2] Arnason & Mo (1977). — [3] Bergner, Zimmer & Münchow (1974). — [4] Percent digestible organic matter (DOM). — [5] Guggolz **et al.** (1971). — [6] Oji **et al.** (1977). — [7] Chomyszcyn & Ziolecka (1972).

BENEFITS FROM AMMONIATION

Nitrogen enrichment: Most straws, stovers, bagasse and other low-quality roughages contain between 0.5 and 1.0 percent nitrogen (N), of which the apparent digestibility is very low. After ammonia treatment it is generally found that the N content of the material is raised by 0.8 to 1.0 percentage units equal to an increase of 5-6 percentage units in crude protein content; in other words, the N content of the feed is roughly doubled. The effect of NH_3 treatment on the digestibility of nitrogen in poor-quality roughages is not yet clear. In experiments with rice straw (Garrett *et al.*, 1974), maize stover (Oji *et al.*, 1977) and wheat straw (Coxworth *et al.*, 1977), the apparent digestibility of nitrogen was decreased, whereas in experiments with barley and oat straw (Sundstøl, 1977, unpublished data) the apparent digestibility of nitrogen was increased by 20-40 percentage units by ammoniation. Mo (1977, unpublished data) found in experiments with growing bulls that the N balance on a ration containing 5 kg NH_3-treated straw and 1.50 kg barley was equal to that on a ration containing 5 kg untreated straw plus 150 g herring meal and 2.15 kg barley. This gives some evidence for a partial utilization of the ammonia N in treated straw. There is no reason to doubt that N bound to the feed through ammoniation can be utilized for protein synthesis in the rumen in a manner similar to other NPN. However, more research is needed to determine if the nitrogen in ammoniated materials is more slowly released in the rumen than that from, say, urea.

TABLE 1. **Influence of ammonia treatment at ambient temperature on enzyme solubility and N content of several straws**

Straw	Enzyme solubility (%)		N content (%)	
	Untreated	Treated	Untreated	Treated
Alfalfa	53	62	2.36	3.24
Barley	37	73	0.53	2.01
Bean	52	65	0.91	2.47
Fescue	37	62	0.79	1.50
Oat	33	63	0.43	1.77
Perennial ryegrass	40	65	1.00	1.92
Rice	29	62	0.56	1.32
Wheat	37	62	0.86	2.14

Source: Weiss **et al.** (1972).

Intake of ammoniated materials: Most experiments conducted so far indicate that ammoniation has a positive effect on the intake of roughage, although reduced palatability of ammoniated high-moisture materials has been observed. When fed in combination with other feeds the intake will depend very much on the amount and nature of the other components of the diet. Together with high-quality hay, grass silage, beets and concentrates, the long form straw is probably the first feed to be refused whether ammoniated or not.

In a Finnish experiment dairy cows consumed 6.9 kg DM of ammoniated and 6.1 kg DM of untreated straw when fed together with beet pulp and concentrates (Rissanen, Kossila and Tuomikoski, 1977). Some of the cows consumed as much as 9 kg of ammonia-treated straw per day. In Danish experiments dairy cows consumed 5.8-6.0 kg DM in ammoniated straw when fed together with 9-10 kg DM in concentrates and fodder beets (Andersen, 1977). In mixed rations, however, an average daily intake of 4-5 kg ammoniated long straw should be regarded as satisfactory for high-yielding dairy cows. Growing cattle will probably consume more (4-6 kg depending on age) when the ammonia-treated straw is fed as the only

roughage together with restricted allowances of concentrate.

Oji *et al.* (1977) found that wether lambs weighing 20-30 kg consumed 949-984 g DM per day of ammonia-treated maize stover compared with 664 g DM of untreated stover. Nedkvitne and Maurtvedt (1977, unpublished data) found that winter-fed ewes weighing 70-80 kg consumed up to 1.1 kg ammoniated oat straw in addition to 1.5 kg grass silage and 0.3 kg concentrate. The animals refused to take similar amounts of wheat straw.

Physical treatment, e.g., chopping and pelleting, as well as supplementation with molasses will most likely have beneficial effects on the intake of ammoniated materials (Table 3).

Digestibility and animal performance: A great number of digestibility experiments have been carried out with ammoniated materials. When comparing results from various experiments a considerable variation is found, most likely due to less than optimum conditions regarding factors influencing the effects of ammoniation. Table 2 summarizes some of the results obtained in digestibility exderiments where ammoniated materials have been fed to sheep.

When ammoniation of straw is performed in a satisfactory manner an increase in organic matter digestibility of 10-15 percentage units is generally achieved. Production experiments indicate that the utilization of the digestible energy is increased as well.

Results of a number of recent comparisons of different methods of improving the feeding value of straw and other crop residues are summarized in Table 3.

Ammonia treatment appears to give a similar or slightly lower improvement in feeding value, compared with methods involving a "dry" treatment with sodium hydroxide, or ensiling with mixtures of sodium and calcium hydroxide. With damp materials, it may be difficult to remove excess free ammonia, resulting in poor intakes (Rounds *et al.*, 1976). In this particular case, combination of such material with acidic silage (to neutralize free ammonia) allowed intakes and rates of gain to rise to values comparable to those obtained with the $NaOH$-$Ca(OH)_2$-treated and ensiled maize cobs. The effect of grinding and pelleting ammoniated straw on improving intake and rate of gain has been demonstrated by Nicholson, Chaplin, Coxworth and Kernan (1977, unpublished data) and Andersen (1977). The additional costs of grinding and pelleting, however, resulted in a similar feed cost per kg of gain.

Nicholson and his co-workers also compared untreated straw with ammonia-treated straw fed as 50 percent of the ration to growing calves (Table 4). In the ration containing 50 percent ammoniated straw, 5 percent of the soya meal was substituted by 5 percent barley. The calves fed the ration containing ammonia-treated straw gained more per day and showed the lowest cost per kg gain compared with the calves on the ration containing 50 percent untreated straw.

To date a limited number of experiments have been carried out with ammoniated materials in rations for dairy cows. In the Finnish experiment referred to above the cows on ammoniated straw yielded 19.4 kg of 4 percent fat corrected milk (FCM) versus 19.0 kg for those fed untreated straw (Rissanen *et al.*, 1977). The intake of concentrate was 8.8 and 9.3 kg and that of beet pulp 1.8 and 2.0 kg for the two groups respectively. In two experiments by Mo (1976, unpublished data) with a total of 48 cows, the animals receiving ammoniated straw produced on average 19.7 kg FCM, whereas the controls produced 19.9 kg FCM. In these experiments the straw made up a relatively small part of the ration, viz. 2.7-3.5 kg per day. In a Canadian experiment ammoniated wheat straw as the only feed did not cover the maintenance requirement for wintering beef cows (Coxworth *et al.*, 1977). When fed together with 1.5 kg rolled barley or in a 50:50 mixture with brome-alfalfa hay the animals maintained their body weight.

Nedkvitne and Maurtvedt (1977, unpublished data) compared 0.6 kg hay with 0.8 kg ammonia-treated straw in addition to 0.3 kg concentrate mixture and 0.37 kg DM in grass silage to winter-fed ewes ($1\frac{1}{2}$-2 years old). From December to March the animals gained similarly. In the last month before lambing the hay-fed ewes gained somewhat more than those fed ammonia-treated straw. However, no significant difference in birth weight of the twins was observed (5.1 kg versus 5.2 kg).

On the basis of the experiments performed and the experience gained it seems reasonable to conclude that the energy value of low-quality roughages, e.g., straw and maize stover, can be raised to that of medium-quality hay by the use of ammonia treatment.

COST AND APPLICABILITY

One of the advantages of the ammoniation method is the low investment required. An established distribution system for ammonia is, however, a prerequisite. This may be organized by farmers through co-operatives or other low-cost channels.

It is difficult to make general estimates of the cost of ammonia treatment. Low-quality roughages are often regarded as waste products with little or no value. In many regions the untreated material is usually collected and stored, and used for fodder, bedding or other purposes. The price of ammonia and plastic will vary over a wide range throughout the world. Since ammonia, plastic, wooden laths and sandbags are the only materials necessary, an attempt will be made to estimate the cost of the treatment at alternative prices.

For a stack such as that described in this article and containing 3 000 kg of straw, the cost of materials may be estimated as follows:

Undersheet 6×6 m = 36 m² plastic Over sheet 10×10 m = 100 m² plastic	Varying price (see Table 5)
22 sandbags	US$4.00
4 wooden laths, 4 m each	US$6.00
Anhydrous ammonia — 3 percent of 3 000 kg = 90 kg	Varying price (see Table 5)

TABLE 3. **Comparisons of ammoniated straw with untreated straw and straw treated with other chemicals: feeding experiments**

		Daily feed intake (g DM)		Daily gain (g)	Feed/ gain	DM digestibility (%)	
I. Cattle							
1. Wheat straw treated with 5% anhydrous ammonia, 98% ration chopped		4 100				53	
cf. treated with 5% NaOH and pelleted		5 200				50	
cf. ensiled with 2% NaOH, 2% $Ca(OH)_2$ and 60% water		4 100				51	
cf. chopped untreated straw		3 100				42	
2. Wheat straw treated with 5% anhydrous ammonia (70% of ration)							
(*a*) ground		6 400		664	9.6	60	
(*b*) pelleted		9 700		1 063	9.2	60	
cf. treated with 5% NaOH and pelleted		8 250		764	10.8	59	
cf. alfalfa (ground)		8 000		995	8.1	64	
3. All bulls received 1 kg hay/day							
A: Grass silage *ad lib.* + 2 kg barley		6 890		1 025	6.7	67.3	(silage)
B: NH_3-treated straw *ad lib.* + 2 kg conc. mix.		6 360		840	7.6	61.2	(NH_3-straw)
C: Pelleted mixture of 70% untreated straw and 30% conc. mix.		8 630		1 087	7.9	62.3	(pellets)
4. Bulls fed 2 kg hay + either 3 kg conc. mix. or 1 kg barley + 50 l distillers' potato residues plus							
A: 3.5 kg untreated barley straw				669		49	
B: 3.5 kg NH_3-treated barley straw				855		63	
Bulls fed 6 kg grass silage + either 3 kg conc. mix. or 1 kg barley + 60 l distillers' potato residues plus							
A: 3.5 kg untreated barley straw				1 161		48	
B: 3.5 kg NH_3-treated barley straw				1 072		53	
5. Steers fed 3 kg grass silage and 2 kg conc. mix./day plus							
Untreated barley straw, Period 1 (287-297 kg)		3 300	straw only	180		48.4	
Untreated barley straw, Period 2 (319-330 kg)		3 400		250			
NH_3-treated barley straw, Period 1 (277-305 kg)		4 000		510		(48.2)	
NH_3-treated barley straw, Period 2 (308-339 kg)		4 600		550			
6. Barley straw fed together with (A): 2 kg and (B): 3 kg DM in other feed to heifers							
Ammonia treated	(A)	4 300	straw only	741	8.5	58	*In vitro*
	(B)	3 700		740	9.1		
Chopped and sliced straw added 4-5% NaOH in a mixer	(A)	4 000		(630)	9.5	74	
	(B)	3 600		784	8.4		
Cobs of straw mixed with 4-5% NaOH	(A)	4 700	straw only	787	8.5	73	
	(B)	3 900		807	8.6		
Untreated straw	(A)	3 700		635	9.0	48	
	(B)	3 400		698	9.2		
II. Sheep							
7. Maize stover ensiled with 3% aq. NH_4OH (approx. 98% of ration)		949				60	
cf. stover ensiled with 2% NaOH and 2% $Ca(OH)_2$		986				58	
cf. untreated stover		664				52	
8. Maize cobs ensiled with 4% aq. NH_4OH (85% of ration)		726		14	54.0		
cf. 50:50 maize silage plus 4% aq. NH_4OH ensiled cobs		1 044		111	9.2		
cf. cobs ensiled with 2% NaOH and 2% $Ca(OH)_2$		1 180		141	8.4		
cf. maize silage		1 044		115	9.1		
9. Rice straw treated with 5% aq. NH_4OH, then pelleted (72% of ration)		1 970		138	15.5		
cf. straw treated with 4% NaOH and pelleted		2 090		133	16.0		
cf. untreated straw pelleted		1 860		89	21.8		
cf. alfalfa hay pelleted		1 710		157	11.1		

Sources: 1. Coxworth **et al.** (1976). — 2. H.H. Nicholson, R. Chaplin, E.M. Coxworth and J.A. Kernan (1977, unpublished). — 3. J. Arnason and T. Matre (1976, unpublished). — 4. S.E. Kvaale and T. Honib (1977, unpublished). — 5. M. Pestalozzi and T. Matre (1977, unpublished). — 6. Andersen (1977). — 7. Oji **et al.** (1977). — 8. Rounds **et al.** (1976). — 9. Walker **et al.** (1976).

To the cost of materials should be added the price of the untreated straw and labour.

If we assume that 100 kg ammoniated straw have the same net energy value as 45 kg barley and that 100 kg untreated straw are equivalent to 25 kg barley, the improvement due to treatment may be equated to the net energy value of 20 kg barley. The lowest and highest costs of treatment in Table 5 (US$1.84 and 6.96) would thus correspond to a price of US$0.09 and 0.35 per kg barley.

By making the stacks twice as long, the costs per unit of plastic can be reduced by approximately 25 percent. Practical experience has also shown that if the plastic is handled gently it can be re-used, thus reducing the cost of the process considerably.

For a stack of a certain size the plastic costs are fixed, so that the cost of treatment will be influenced by the amount of material in the stack. If the bales are of a low density type, one may get as little as 2 000 kg per stack, whereas with high density bales there may be as much as 4 000 kg of straw per stack.

As mentioned earlier, the treatment seems to be effective for a great variety of waste materials. The process is inexpensive and the amounts of materials and "know-how" needed are limited, indicating that the ammoniation method should be applicable over a wide range of conditions. In some countries ammonia and polyethylene may not be easily available but this problem might be overcome if a real demand exists. Furthermore certain fresh forages, such as maize stover, are known to contain a high urease activity, enabling urea to serve as a source of ammonia.

One disadvantage is that the excess ammonia, i.e., roughly 2/3 of the ammonia, is lost when the stack is opened. Whether this can be collected and re-used economically, e.g., by leading the gas mixture from the stack through water, is not yet clear.

Experiments with straw containing up to 50 percent moisture have shown that the ammonia has a definite fungicidal effect in closed stacks Even after the stack has been opened there is some evidence of an improved keeping capacity in high-moisture straw (Westgaard and Torgrimsby, 1977). Thus the ammoniation method not only improves the digestibility of roughages but also serves as a conservation and storing method. If a high-moisture material is stacked, ammonia should be added immediately to avoid mould and other damage.

Another advantage of the ammonia treatment is that the germinating capacity of wild oats and probably some other weed seeds is destroyed during the treatment.

Ammonia and its derivatives are important nitrogen fertilizers. Their use for improving the yield of food crops may have precedence over the use of ammonia to improve the feeding value of straw for ruminant animals. However, the use of small amounts of ammonia to improve the feeding value of straw and other poor-quality roughages can improve significantly the stability of feed supplies of ruminant animals. The latter are for the most part dependent on pasture and hay that often come from land which cannot grow food for direct human consumption. Thus the two uses of ammonia should not be in serious conflict; in fact, they may more properly be regarded as complementary.

Tropical pastures can have very high carrying capacities for cattle in the rainy season, but a very low carrying capacity in the dry season. In the absence of alternate feed supplies to tide the animals through the dry season, the cattle population that could be carried at this time of year would be inadequate to take full advantage of the forage produced in

TABLE 4. **A comparison of untreated versus ammonia-treated wheat straw in rations for growing beef calves**

	Untreated straw containing ration	Ammoniated [1] straw containing ration
Ingredient composition of ration, %		
Wheat straw (ground 1.9 cm screen, not pelleted)	50	50
Barley	32.75	37.75
Soya meal	15	10
Vitamins, minerals	2.25	2.25
Cost of ration ($ Can./ton)	89.72	88.62
Feed consumed, kg/day	5.5	5.9
Gain, kg/day	0.39	0.53
Feed/gain	14.4	11.2
Cost/kg gain ($ Can.)	1.29	0.99

Source: H.H. Nicholson, R. Chaplin, E. Coxworth and J.A. Kernan (1977 - unpublished).

[1] Treated with 3.5% NH_3 for minimum 30 days. Cost of treatment calculated to be $16.54/ton (ammonia, plastic and labour).

TABLE 5. **Cost of ammonia treatment of straw according to the stack method**

Cost per kg anhydrous ammonia	Cost per m² plastic foil (US$)		
	0.20	0.50	0.80
	Cost per 100 kg ammoniated straw (US$)		
0.20	1.84	3.20	4.56
0.60	3.04	4.40	5.76
1.00	4.23	5.60	6.96

the rainy season. Ammonia treatment of crop residues and other poor-quality roughages might be one method of improving feed supplies in the dry season.

CONCLUSIONS

- Ammonia treatment of low-quality roughages is simple and could be easily adopted by farmers.
- The method is relatively inexpensive.
- The process creates no known pollution problem.
- Ammonia acts as a preservative of high-moisture materials.
- The treated material is dry and easy to handle.
- The treated material also contains no compound (such as NaOH) that creates stress in the animal consuming it.
- The germinating capacity of some weed seeds is destroyed during ammonia treatment.
- Non-protein nitrogen is added to the material in the process.
- Treated material is more palatable to livestock than untreated material.
- The energy value of waste materials like cereal straw and maize stover may be increased by as much as 70-80 percent above that of untreated material by this process.
- Ammonia is an unpleasant chemical to handle.
- Some of the ammonia is lost when opening the container in which the ammoniated material is preserved.

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The importance of helminth infections in ruminants

H. Herlich

Parasitic helminths — the roundworms (nematodes), flukes (trematodes), and tapeworms (cestodes) — infect all classes of livestock and their related wildlife species throughout the world. It is probable that every animal raised for human use is infected with helminths during part or all of its life span. Hundreds of helminth species have been identified and described as parasites of livestock, and they have been recovered from virtually every tissue and organ in the host animal. Livestock are not only the primary or definitive hosts harbouring the sexually mature parasite of most of these helminth species but serve also as intermediate hosts harbouring the asexual larval stages of several species that parasitize man and carnivores.

The economic impact of helminth diseases on livestock encompasses mortality losses, morbidity losses (measured in terms of less than optimum production of milk, meat and wool), enhanced susceptibility to bacterial and viral diseases, and losses resulting from condemnation of carcasses and organs, as well as the cost of drugs and veterinary care. Although accurate figures are difficult, if not impossible, to arrive at, some indications of the magnitude of these losses are available.

It has been reported that worldwide about 50 million cattle and buffaloes and about 100 million sheep and goats die annually from all diseases and that the morbidity loss is probably the same (Byerly, 1977). It is not unrealistic to attribute at least 5-10 percent of the mortality losses and 10-20 percent of the morbidity losses to helminth diseases, corresponding to an estimated annual loss equivalent of about 10 million cattle and buffaloes and 30 million sheep and goats. Over and above these direct losses is the incalculable but extremely important loss that results from inefficient forage and feed conversion that is inevitable in parasitized livestock. Finally, there is the loss entailed in costs of drugs and veterinary care. Annual sales of drugs for use as anthelmintics in ruminants are running at about US$50 million in the U.S. alone and about NZ$12 million in New Zealand. Conservative extrapolation of these sums to account for anthelmintics sales worldwide would suggest perhaps as much as US$500 million.

In a world confronted with an ever-rising human population and an increasing demand for animal protein, the enormous qualitative and quantitative losses caused by helminth parasites — the silent predators — are intolerable. Of the great number of known species of helminth parasites of ruminants, perhaps about 70 species living in the gastrointestinal tract, the lungs, and the liver are of greatest economic importance (these are listed in the table). The epizootiology, pathogenesis, and control of some of these parasites will be briefly reviewed.

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NEMATODES

Gastro-intestinal nematodiasis. This syndrome is caused by a mixture of numerous species of nematodes parasitic in the abomasum and the small and large intestines. Generally these parasites have a direct life cycle (Figure 1). The infective stage for most species is a free-living larva, which is swallowed by the grazing susceptible animal; after the parasite reaches its proper niche in the gastrointestinal tract, it grows and matures. Adult males and females mate, and the females release eggs that are passed with the host's faeces back on to the ground, where once again the infective stage is reached. Under optimum conditions — moisture and mild temperature — the infective stage may be reached in as few as three days. The infective free-living stages are generally very resistant to environmental factors and may survive for months, extended drought being the most severe challenge to their survival.

Variations from this basic life cycle occur. Hookworms (*Bunostomum* spp.) and intestinal threadworms (*Strongyloides* spp.) may infect ruminants via the normal oral route and also by skin penetration. Transmammary infection — passage of larvae in the colostrum — occurs with *Toxocara vitulorum* in water buffaloes and in cattle.

Most of the gastro-intestinal nematodes grow and develop in the superficial mucosal layers of the digestive tract or in the gastric pits of the stomach and the intervillar spaces of the intestine. Hookworms, threadworms, and ascarids have a more extensive migration through the circulatory system, liver, and lungs before reaching the small intestine for final maturation. The depth of tissue penetration and the length of time that the larvae remain in the tissues vary among the nematode species.

The principal clinical signs of gastro-intestinal nematodiasis are anorexia, diarrhoea, and emaciation (Figure 2). When stomach worms (*Haemonchus* spp.), hookworms (*Bunostomum* spp.) and the nodular worms (*Oesophagostomum* spp.) are present in large numbers there is a marked haemorrhagic anaemia. Other species of gastro-intestinal nematodes have been implicated in anaemias of non-haemorrhagic origin, e.g., impaired erythropoiesis caused by *Ostertagia osteragi* in cattle.

Destruction of gastric and intestinal mucosa by nematodes results in a wide array of pathophysiologic disturbances. For example, the pH of gastric contents may shift from highly acid to neutral or alkaline, serum pepsinogen may become elevated, and there may be leakage of albumin which is reflected as a hypoproteinaemia. The levels of various intestinal enzymes — maltase, alkaline phosphatase — may be reduced, and frequently there is hypoglycaemia and hepophosphataemia. These pathologic alterations suggest impaired digestion and malabsorption of nutriments in severely affected animals; however, evidence of these digestive malfunctions is not unequivocal. It appears that gastro-intestinal

ECONOMICALLY IMPORTANT HELMINTH PARASITES OF RUMINANTS

Nematodes of abomasum

Haemonchus contortus
Haemonchus placei
Haemonchus similis
Mecistocirrus digitatus
Ostertagia circumcincta
Ostertagia crimensis
Ostertagia lyrata
Ostertagia marshalli (Marshallagia marshalli)
Ostertagia mentulata
Ostertagia occidentalis
Ostertagia ostertagi
Ostertagia pinnata
Ostertagia trifurcata
Teladorsagia davtiani
Trichostrongylus axei

Nematodes of small intestine

Bunostomum phlebotomum
Bunostomum trigonocephalum
Capillaria bovis
Cooperia bisonis
Cooperia curticei
Cooperia momasteri
Cooperia oncophora
Cooperia pectinata
Cooperia punctata
Nematodirus abnormalis
Nematodirus battus
Nematodirus filicollis
Nematodirus helvetianus
Nematodirus spathiger
Paracooperia nodulosa
Strongyloides papillosus
Toxocara (= Neoascaris) vitulorum
Trichostrongylus axei
Trichostrongylus capricola
Trichostrongylus colubriformis
Trichostrongylus falculatus
Trichostrongylus longispicularis
Trichostrongylus probolurus
Trichostrongylus rugatus
Trichostrongylus vitrinus

Nematodes of large intestine

Chabertia ovina
Oesophagostomum columbianum
Oesophagostomum radiatum
Oesophagostomum venulosum
Skrjabinema alata
Skrjabinema ovis
Trichuris discolor
Trichuris globulosa
Trichuris ovis
Trichuris skrjabini

Nematodes of respiratory system (lungworms)

Dictyocaulus filaria
Dictyocaulus viviparus
Muellerius capillaris
Protostrongylus rufescens

Cestodes (tapeworms)

Moniezia benedeni
Moniezia expansa
Thysanosoma actinioides

Larval cestodes - ruminants as intermediate hosts

Coenurus cerebralis
Cysticercus bovis
Cysticercus ovis
Cysticercus tenuicollis
Hydatid cyst (Echinococcus granulosus)

Trematodes

Cotylophoron cotylophorum
Cotylophoron indicum
Dicrocoelium dendriticum
Fasciola gigantica
Fasciola hepatica
Fascioloides magna
Paramphistomum cervi
Paramphistomum microbothrioides
Paramphistomum microbothrium
Schistosoma bovis
Schistosoma mattheei
Schistosoma spindale

nematodes exert their pathogenic effects primarily by inducing anorexia and serum protein losses, both of which affect protein metabolism (Symons, 1976).

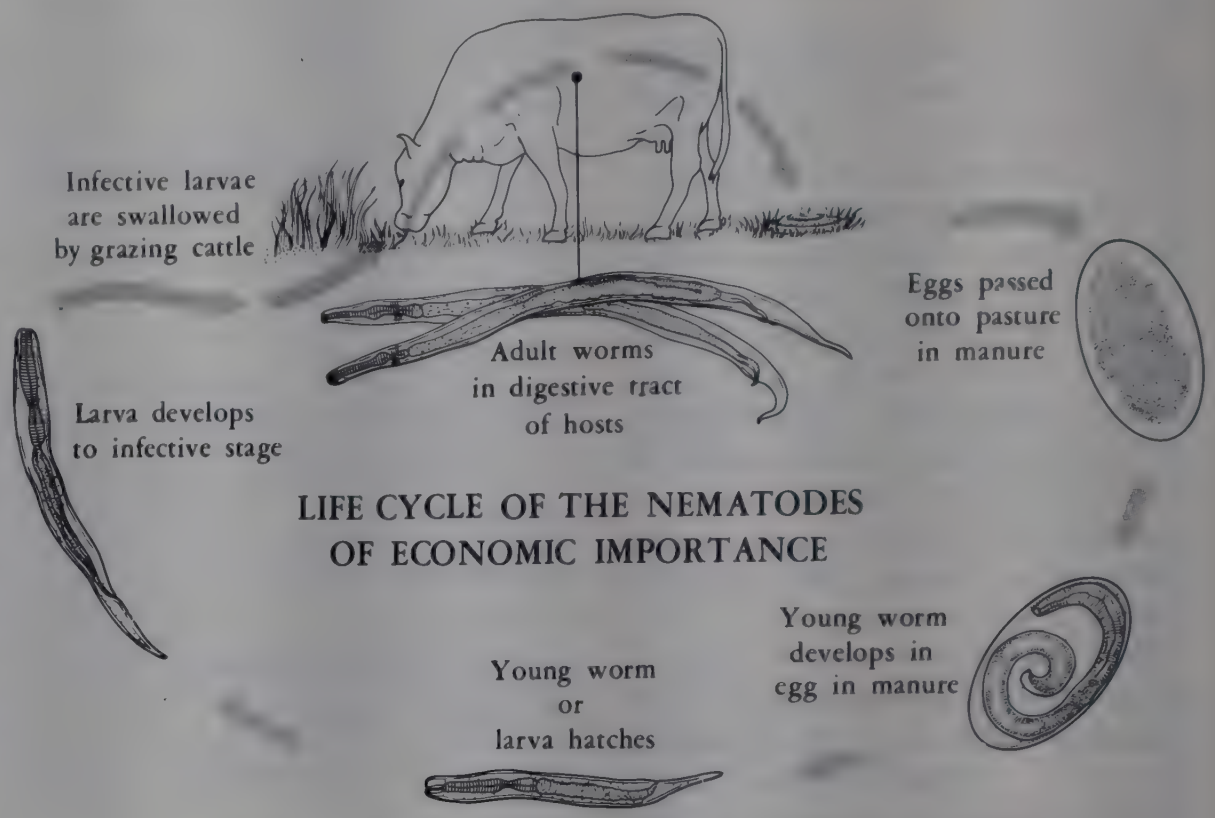
Lungworm disease. Authough several genera of nematodes are parasitic in the lungs of ruminants, only members of the genus *Dictyocaulus* appear to be of widespread importance. *Dictyocaulus* spp. have a direct life cycle; the infective larvae are swallowed along with grazed herbage, reach the small intestine where they penetrate the wall to enter the lymphatic system, and eventually reach the lungs where they become sexually mature. The life cycle of the protostrongyline lungworms (*Protostrongylus* spp.) involves snails and slugs as intermediate hosts, but otherwise it is similar to that of *Dictyocaulus* spp. Eggs containing the first-stage larvae are released by females in the lungs, coughed up the trachea, and swallowed through the oesophagus. The eggs hatch during passage through the gut and the larvae are expelled with the faeces on to the ground.

Migration to and penetration of lung tissue by the larvae result in emphysema, petechial haemorrhages, bronchitis, and pneumonia. Infections may be fatal or may be self-limiting; in the latter type most worms are expelled within a few weeks after reaching the adult stage, and, once recovered, the livestock are usually immune to further infection.

TREMATODES

Liver flukes. Fascioliasis is caused by invasion of the livers of ruminants by the flukes, *Fasciola hepatica* and *Fasciola gigantica*. The life cycle and pathogenicity of both species are essentially the same.

The life cycle is depicted in Figure 3. Generally, snails of the family Lymnaeidae serve as the intermediate host. The cercariae released by the snails encyst on grass and are ingested by the grazing ruminant. The parasite excysts in the small intestine, penetrates the wall, enters the abdominal cavity, and then reaches and finally penetrates the liver. The immature fluke continuously migrates in the liver parenchyma for several weeks and then enters the bile ducts, where it attains sexual maturity.


Infective larvae are swallowed by grazing cattle
Eggs passed onto pasture in manure
Adult worms in digestive tract of hosts
Larva develops to infective stage
Young worm develops in egg in manure
Young worm or larva hatches

LIFE CYCLE OF THE NEMATODES OF ECONOMIC IMPORTANCE

FIGURE 1. Life cycle of nematodes of economic importance

Cr: R.B. Ewing

Fascioliasis may be acute as a result of extensive destruction of hepatic tissue and accompanying haemorrhage if enormous numbers of flukes are migrating in the liver. The animal may die before any sign of disease appears. Acute fascioliasis is not uncommon in sheep; however, the chronic form of disease is more frequently seen in cattle. In chronic fascioliasis, affected animals are anaemic, emaciated, weak, and generally non-productive, but they may survive for years. In sub-acute fascioliasis the animal usually dies within a few weeks after the onset of clinical signs of disease. Cattle appear to be able to acquire immunity against the flukes, but sheep do not (Soulsby, 1965).

Dicrocoelium dendriticum, another trematode causing liver damage, has a life cycle which differs from that of *Fasciola* spp. in that it involves ants as a second intermediate host. The geographic distribution of this fluke is more limited, being found principally in Europe. Its pathogenicity is similar to but generally less severe than that of *F. hepatica* and *F. gigantica*.

Intestinal flukes. Other worldwide trematodes of lesser importance are the amphistomes (*Cotylophoron* spp. and *Paramphistomum* spp.) which parasitize the rumen after spending the early phases of their development in the duodenum and proximal ileum. The adult stage apparently does little damage, but when massive numbers of the immature stages are present, these destroy intestinal tissue and may cause diarrhoea and anaemia.

Blood flukes. The schistosomes (*Schistosoma* spp.), of which distribution is largely limited to Africa and Asia, live in the circulatory system and, depending on the species, are found in mesenteric, portal, pancreatic and pelvic veins; one species in Asia inhabits the nasal veins. Unlike the liver flukes and the amphistomes, the schistosomes infect ruminants when the cercaria actively penetrates the skin. Pathogenicity is directly related to the number of adult flukes and egg production,

because the principal damage to the host is caused by the lesions formed by host tissues in response to egg deposition. Clinical signs may include diarrhoea alternating with constipation and anaemia.

CESTODES

Adult tapeworms. The common tapeworms of ruminants belong to two genera, *Moniezia* and *Thysanosoma*. The life cycle of all species requires an intermediate host, generally an oribatid mite. The parasites are ubiquitous in geographic distribution, and the incidence of infection is high. However, the overwhelming evidence from field and laboratory studies is that with rare exceptions the parasites are not harmful to their hosts. If an animal should acquire enormous numbers, there is the possibility of occlusion of the small intestine by *Moniezia* spp. and of the bile ducts by *Thysanosoma actinioides*.

FIGURE 2. Helminth-infected calf showing prominent signs of parasitism: diarrhoea, rough coat, submandibular oedema and emaciation.

Larval tapeworms. Ruminants serve as intermediate hosts for a number of tapeworms which are parasitic in their adult stages in the small intestine of man or carnivores, the definitive host and sometimes the intermediate host depending upon the species of tapeworm concerned. Thus, *Cysticercus bovis* which is the larval stage of *Taenia saginata*, a tapeworm of man, develops in the musculature of cattle. The cystic larval stage is not pathogenic for cattle, its importance being related to its public health significance and the resultant losses caused by treating infected carcasses (either by refrigeration or by cooking) to render them safe for human consumption; moreover, grossly infected carcasses may be totally condemned at meat inspection.

Coenurus cerebralis, the larval stage of *Taenia multiceps*, a parasite of carnivores, is harmful to ruminants, which are infected by ingestion of the egg of the tapeworm, the larva reaching and developing in the central nervous system, predominantly the brain. The lesions produced by larval cysts cause clinical signs that include staggered, unsure gait and ataxia, a condition commonly called "gid" (the affected animal may gnash its teeth and display tremors of the head). Despite these rather dramatic signs of distress, affected animals usually continue in good health and recover unaided (Smyth and Heath, 1970).

Hydatid cysts are the larval stage of *Echinococcus granulosus*, a small tapeworm of the dog. Following the ingestion of eggs excreted by the dog, the cysts develop in the viscera of ruminants and some other intermediate hosts. The dog becomes infected when it eats uncooked, infected offal. Echinococcosis is a serious public health problem because hydatid cysts can develop in man through the inadvertent consumption of *Echinococcus* eggs excreted by dogs.

CONTROL

Ideally, control of helminth parasites should be effected by preventive management practices aimed at reducing the level of contamination of the herbage grazed and the exposure of susceptible stock to the infective stages of the parasites. This approach to control is deceptively simple. In reality it is difficult, if not impossible, to incorporate beneficial management practices — pasture rotation, improved drainage, optimum stocking rate, and segregated grazing of young and adult livestock — and still derive the most efficient use of the pasture. In Australia it has been reported that mixed or alternate grazing with cattle and sheep is beneficial in controlling gastro-intestinal parasitism, the theory being that cattle decontaminate the pasture of those helminth parasites of sheep that are unable to complete their life cycle in cattle and vice versa. Complicating this approach, however, is the fact that both host species share several species of pathogenic parasites.

Inevitably, effective control of gastro-intestinal nematodes is dependent on the use of chemical agents such as anthelmintics. A great number of safe and highly effective anthelmintics are now available with a very broad spectrum of activity against the immature and adult stages of most of the important helminth parasites of ruminants (Gibson, 1975). These may be administered in a variety of ways: oral liquid drenches, boluses, capsules, pastes, top dressing on feed, and injection. Frequency and method of administration, and whether they are used therapeutically, prophylac-

tically, or strategically, depend upon the vagaries inherent in each individual livestock operation.

Two phenomena of the utmost importance in respect to use of anthelmintics must be noted. Strains of at least two species of nematodes parasitic in sheep have become highly resistant to such anthelmintics as phenothiazine and some of the benzimidazoles. This resistance may be overcome by use of higher than recommended therapeutic dosages and by use of alternate anthelmintics to which the parasites are still highly susceptible.

The second phenomenon is hypobiosis. This refers to a physiological state, analogous to diapause of insects, in which early fourth-stage larvae of certain strains of nematode parasites (notably *Ostertagia* spp.) remain inhibited in their development within the host for up to several months, in contrast to a normal developmental period of just a few days. These hypobiotic larvae are highly resistant to most of the anthelmintics that are highly active against normal immature worms. There are reports that some newer compounds are highly active against hypobiotic larvae.

As is the case with gastro-intestinal nematodes, control of lungworms by management alone is generally unsatisfactory and impractical. Satisfactory anthelmintics are available and these should be used as soon as livestock show clinical signs of lungworm infection and diagnostic confirmation is obtained. Infection with lungworm is diagnosed by demonstrating the first-stage larvae in the faeces.

In the U.K. and elsewhere in Europe lungworm disease of cattle has been effectively prevented by vaccination. The vaccine consists of inoculating calves with infective larvae that have been irradiated at an X-ray exposure level that causes aborted early development in the host without impairment of their ability to stimulate an immune response. In essence then, vaccination is a controlled and abbreviated infection that exploits the host's ability to acquire resistance to re-infection

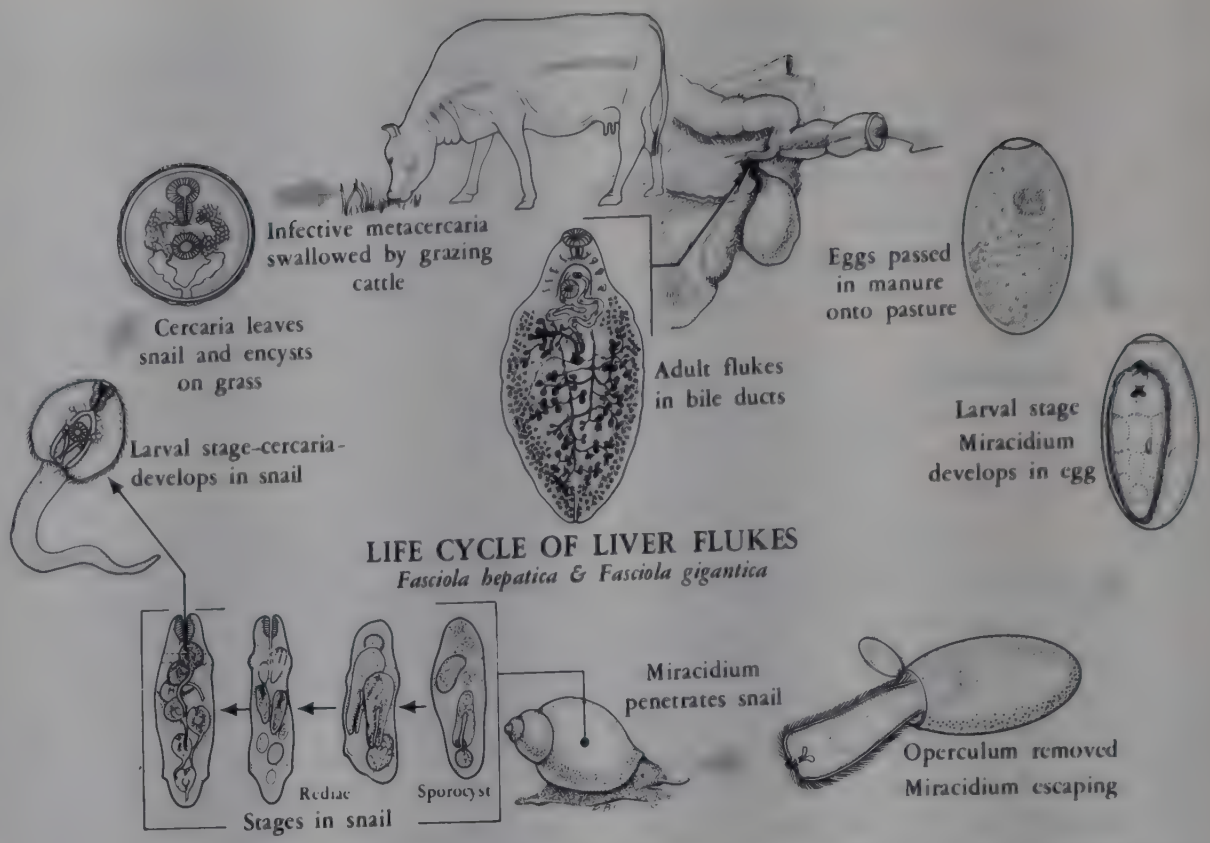

Infective metacercaria swallowed by grazing cattle
Eggs passed in manure onto pasture
Cercaria leaves snail and encysts on grass
Adult flukes in bile ducts
Larval stage Miracidium develops in egg
Larval stage-cercaria-develops in snail
LIFE CYCLE OF LIVER FLUKES
Fasciola hepatica & Fasciola gigantica
Miracidium penetrates snail
Operculum removed Miracidium escaping
Rediae
Sporocyst
Stages in snail

FIGURE 3. Life cycle of liver flukes Cr: R.B. Ewing

Much research has been aimed at developing comparable vaccines against other helminth parasites but with little success.

SUMMARY

Helminth parasitism is a herd or flock problem which is generally characterized by poor growth of young animals. As a rule, the greater the number of infective stages gaining entrance into the host in a shorter interval of time, the more severe the pathogenic effects on the host. The effects may range from innocuous to fatal; the severity of infection is modulated by the inherent pathogenicity of the species of parasites and the age, nutritive condition, and immunologic status of the host. Generally, young growing animals are more seriously affected than adult stock; well-fed animals (good level of protein) are better able than poorly fed animals to tolerate infections, and varying degrees of immunity to re-infection may be acquired.

Ideally, control of helminthic infections incorporates management programmes that reduce the parasitic infection of the areas housed or grazed by livestock and the exposure of susceptible stock to the infective stages of the parasites. Practically, however, control of helminth disease is effected through selective and judicious use of a wide array of safe, highly effective anthelmintic chemicals.

Helminth parasitism of ruminants is responsible for enormous mortality and morbidity losses that are largely preventable and unacceptable in a world requiring constantly increasing sources of animal protein. ■

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Control of equine infectious anaemia in horses

L. Coggins

Equine infectious anaemia, often called swamp fever, is an infectious viral disease of horses, ponies, mules and donkeys. It has been diagnosed in practically every country where large numbers of equines are assembled. The disease may occur as an acute, subacute or chronic illness, but has a marked tendency to assume a subclinical form.

An immunodiffusion (ID) test for the diagnosis of equine infectious anaemia (EIA), first described by Coggins and Narcross in 1970, has proved to be a very accurate and reliable technique for the diagnosis of all forms of EIA in horses (Coggins, Narcross and Nusbaum, 1972). In this article the use of the ID test in the control of EIA is discussed.

Clinical signs. The clinical symptoms of EIA (Dreguss and Lombard, 1954) vary depending on the stage of infection, but in general the affected animals show irregularly recurring episodes of fever, marked depression, progressive weakness, loss of weight, oedema of the abdomen, sheath and legs, and anaemia of a transitory or progressive type for a variable period after initial infection (Figure 1). Anaemia is usually more pronounced during subsequent recurring febrile episodes. An enlarged spleen can often be palpated on rectal examination. Affected horses may die suddenly or, as is more often the case, show signs of improvement only to have recurring lapses of illness for months or years, especially if intensively worked or trained. Many horses recover so that they no longer exhibit clinical signs, yet continue to have virulent virus in their bloodstreams throughout their lifetime. Such horses, commonly referred to as "carriers", are potentially infectious for susceptible horses.

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Outbreaks. Natural outbreaks of acute and subacute cases of this disease occur during the summer and early autumn months in temperate zones which coincide with the peak population of biting insects, especially blood-sucking horseflies (tabanids). The transfer of infectious blood from carriers to other horses by these insect vectors is believed to be an important cause of natural outbreaks. Active cases of EIA may be especially numerous near swampy areas where biting insects are abundant: hence the name swamp fever. Mare-to-foal transmission *in utero* or by ingestion of colostrum is a common means of infection in foals (Kemen and Coggins, 1972). Infection is then transmitted from these foals to other horses by insects. Transmission via contaminated hypodermic needles or other instruments may produce new infections at any time, and likewise recurring clinical episodes in a chronic carrier may also occur at any time of the year.

Prevalence and losses. Using the ID test, surveys of horses for EIA have been made in most states in the United States and other countries. The incidence among states varies, but has usually been found to be between 1.5 and 10 percent. The highest rates of infection have been in horses pastured in river valleys in the warmer climates. The incidence of EIA in some tropical countries has been as high as 30 percent; the denser fly population in these areas and the ease of transmission of EIA among horses at pasture probably account for these findings.

A correlation between EIA infection and inability of racehorses to perform has been documented (Coggins and Auchnie, 1977). However, total losses due to EIA infection are difficult to assess because of fear and stigma frequently associated with the EIA virus-infected horse which results in most test-positive horses being destroyed before their performance

FIGURE 1. Horse chronically infected with EIA showing depression, weight loss and oedema of abdomen and hind legs.

can be accurately determined under a variety of conditions. Circumstantial evidence, however, suggests that many apparent carriers can perform as normal horses.

Immunodiffusion test. The ID test for EIA is a laboratory serologic procedure which detects precipitating antibody specific for EIA. Briefly, the technique involves cutting wells in a layer of 1 percent agar in a petri dish. Six wells 7 mm in diameter are spaced 3 mm apart around a central reservoir of the same diameter containing viral antigen. Reference serum which reacts with EIA antigen to form a well-defined specific precipitin line is placed in every other outside well (Figure 2). Serum to be tested is placed in the remaining three outside wells. This well arrangement facilitates an accurate determination of a line of identity (i.e., the coalescence of the suspect precipitin line with the control line), and maximizes the sensitivity of the ID test.

The ID test is incubated at ambient room temperature in a humid chamber and observed each day over a strong narrow beam of light and against a black background for evidence of precipitin lines. Control lines and strong reactions are visible at 24 hours, but weak reactions which may be seen as a slight inward bending of the control lines are often not distinct until after 48 hours. Serum containing high titres of antibody (1:32 or greater) produces broad, diffuse precipitin bands near the antigen well (Figure 2, well 2), but these reactions can be confirmed by diluting the serum 1:4 and re-testing. The strong reactions need not be overlooked because the reference lines fuse into the reaction and stop before they reach the suspect serum well.

Any adult horse that is positive in the ID should be considered to be infected. Weak reactions also indicate that the horse is infected, except in the case of foals nursing infected mares in which colostral antibodies may persist in the serum for up to 5 months even though the foal is not infected. In such cases the foal should test negative after 6 months of age.

Standardization of test. In the United States the Department of Agriculture (USDA) has standardized the EIA test reagents and laboratory procedures by adopting a standard protocol (Pearson, Coggins and House, 1975) and controlling the sale of reagents to only officially approved diagnostic laboratories. Technicians in the approved laboratories must undergo a period of training at the USDA Centre and prove their proficiency on annual check tests.

Internationally, a committee of the IVth International Conference on Equine Infectious Diseases (Toma, 1976) was formed to standardize the results of EIA tests on a worldwide basis. Toward this objective a sterile,

FIGURE 2. Immunodiffusion test for EIA. Antigen is placed in centre well, reference serum in wells 1, 3 and 5. Serum to be tested is placed in wells 2, 4 and 6. Reaction at wells 2 and 4 is positive; at well 6 it is negative.

FIGURE 3. Canopy trap for collecting tabanid horseflies (Adkins, Ezell, Sheppard & Askey, 1972).

heat-inactivated, lyophilized reference serum has been made available to interested diagnostic laboratories. This serum represents the minimum level of EIA antibody which should be detected by all laboratories.

What can be done about EIA? It is generally accepted among the scientific community that EIA-infected horses are viraemic carriers for life even though they may not exhibit clinical signs of illness for long periods of time. However, explosive outbreaks of EIA are more often associated with clinically sick and dying horses. The unapparent carrier seems to transmit EIA less frequently, but experimental data show that apparently healthy EIA carrier mares can infect their foals, although usually less frequently than clinically ill mares (Kemen and Coggins, 1972). Transmission of EIA by horseflies has been demonstrated from an infected pony which had not shown clinical signs within the previous month; but transmission of EIA by flies from horses that have not been clinically ill for several years has been so far unsuccessful. Thus, it is concluded that all test-positive horses are viraemic and that consequently all reactors are potential spreaders of the infection, even though some unapparent carriers represent very minimal risks, especially if they are kept under conditions which prevent transmission by blood-sucking insects.

The following is a suggested programme for effective control of EIA at the farm, area, state or country level:

- test and identify all reactors;
- segregate, isolate and/or destroy all infected horses;
- test all incoming horses to prevent re-introduction of EIA carriers;
- control needles and blood-sucking insects (Figure 3), especially if all carriers are not to be destroyed immediately; and
- isolate foals out of positive mares and re-test after 6 months of age to ascertain whether they are infected or not before exposing other horses to them.

The above approach has been applied by individual farms which have remained free from EIA regardless of the disease status on neighbouring farms.

Some states in the United States have adopted regulations aimed at limiting the spread of EIA. These programmes require a negative ID test prior to admission of any horse to a state-supported show or fair, the sale or other change of ownership of the horse, any importation of horses into the state, and movement of horses within the state on a public highway. Under such programmes all positive reactors are quarantined, re-tested to confirm continuing infection, and permanently identified with a freeze brand. Branded horses must be quarantined by isolation on a farm or destroyed.

Complete testing of all horses and destruction of all reactors have been used to eradicate the disease in Hong Kong; to remain free, however, the colony has to prevent the re-introduction of the disease by testing all horses before importation. If other countries wished to remain free of EIA they would have to follow similar control measures.

The tools and methods for the control of EIA are available, but whether many countries will opt for eradication remains to be seen. There are political and emotional issues which must be faced in the control and eradication of such a disease (Kemen, 1977). ■

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The Newcastle diseases

R P. Hanson

Strains of Newcastle disease virus (NDV) that kill more than 90 percent of susceptible adult chickens have been isolated in North and South America, Europe, Africa and Asia following a second panzootic of the disease (Figure 1). Strains of virus that produce no apparent disease also have been isolated on all continents.

The virus is readily isolated from chickens having Newcastle disease by inoculating eluates from tracheal or cloacal swabs or tissue suspensions into chicken embryos. Growth of the virus produces haemagglutinins in the allantoic fluids in two to three days and usually kills the embryo. The serological identity of the viral haemagglutinin is then determined by neutralization or inhibition of its activity with specific antisera. Using this technique of isolation and identification, virologists have learned that NDV is a savage killer of chickens in one place and a tame immunizer in another.

The question of how much the property of virulence is attributable to the strain of virus and how much to the stock of chickens and to local environmental factors was answered more than 20 years ago, when preparations of two virus strains of high virulence and two of moderate virulence were titrated simultaneously in Wisconsin and Italy in locally available chickens. The location had no effect; the highly virulent strains performed the same in Italy and Wisconsin, as did the moderately virulent strains (Mantovani *et al.*, 1954).

Virulent strains. Since then a great deal more about the nature of highly virulent strains has been learned, as well as about those of low virulence (Table 1). The virulent strains are obtained from two forms of the disease. The first, known in the United States as the Asiatic type or the viscerotropic velogenic (vv) form, was initially described by Doyle in England in 1926. Most susceptible adult birds infected with it die in 4 to 8 days. The second form, called pneumoencephalitis by Beach, who described it in 1942, is also known as the neurologic velogenic form. The disease produced is less acute, and mortality is more variable. Either type of disease may be highly or moderately communicable. Facial oedema and diarrhoea are usual but not invariable signs of Doyle's disease, and haemorrhages in the gut are almost always found at death. Because of the acuteness of Doyle's disease neurologic signs, particularly tremor and postural distortions which are the hallmark of Beach's disease, are infrequently seen.

Highly virulent strains contain several subpopulations that are differentiated by the type of plaque produced in chick embryo monolayers. Invariably virulent isolates contain large clear plaque formers and usually large red ones as well; they may also have small red and small clear plaque formers. Clones derived from large plaques are highly virulent for chickens. Clones obtained from small plaques are of much lower virulence, and may be almost avirulent. Virus of virulent clones adsorbs to cells more rapidly than does virus of avirulent clones, replicates more rapidly in cells, and has a stronger affinity for a wide range of cells. Virulent clones kill chicken embryos within half the time required by avirulent clones and are more toxic to mammals (Schloer and Hanson, 1968).

Avirulent strains. Avirulent isolates are readily differentiated from virulent isolates in chicken embryos and cell cultures. Although haemagglutinins are usually produced in 48 hours by these isolates, as they are also by virulent strains that kill embryos in that time, the embryos infected by avirulent strains continue to live for another 48 to 96 hours. On chicken embryo fibroblast monolayers in which virulent strains produce large and small plaques, avirulent strains produce either no plaques at all or, rarely, microplaques. However, avirulent strains will consistently produce very small plaques on mono-

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layers if magnesium and DEAE (diethylaminoethyl ether) are added to the overlay (Barahona and Hanson, 1968), or if trypsin is added (Nagai, Klenk and Rath, 1976).

While the origins of the virulent and avirulent forms of NDV have not been determined, there is evidence that both have reservoirs in wild bird populations, and that viruses from these reservoirs are periodically introduced into domestic fowl. Avirulent virus, and only avirulent virus, is readily isolated from migratory waterfowl in North America (Rosenberger, Krauss and Slemons, 1974). These isolates are not distinguishable from the chicken isolates of Australia and Northern Ireland or from some turkey isolates that have been recovered in the United States. They differ in one characteristic, high thermostability, from the avirulent and thermolabile isolates recovered from chickens in the United States and the United Kingdom.

Virulent strains have been recovered from psittacines and other nonmigratory tropical birds and some have exhibited the highest degree of virulence for chickens that has been observed. It may be significant that the first isolates from chickens during the 1971 epizootic in southern California, which originated from infected parrots, were more virulent than the isolates recovered many months later during the last stages of that epizootic (Schloer, Spalatin and Hanson, 1975). This is reminiscent of the declining virulence for rabbits of the myxomatosis virus that occurred in Australia after that disease became established in the feral rabbit population. The history of Newcastle disease is consistent with repeated introduction of virulent and contagious viruses into poultry and the spread of these viruses through susceptible flocks of a region and sometimes throughout the world. Each of these epizootics or panzootics fades in the face of the exhaustion of the susceptible population and the implementation of control measures (Hanson, 1977; Lancaster and Alexander, 1975).

Diagnosis. The varied virulence and the variety of diseases expressed by NDV make it imperative that the virus be isolated and identified from every outbreak of the disease (Table 2). Inoculation of 9-day-old embryonat-

FIGURE 1. Spread of peracute Newcastle disease, 1962-72

Source: University of Wisconsin

ing eggs into the allantoic chamber is the preferred method (Figure 2). Allantoic fluids are harvested 48 to 96 hours after inoculation (following death if it occurs during that period or from living embryos if it does not), tested for haemagglutinins and, if present, for their inhibition by specific antisera. Isolation can also be accomplished in cell cultures, but a more elaborate protocol is needed. Serological tests, using either haemagglutination inhibition or virus neutralization in embryos or cell cultures, readily detects antibody and signifies past experience with the infection. Serological methods are most useful in evaluating the status of a flock of chickens and in measuring its response to vaccination (Hitchner, 1976). Serologic tests are less useful and may be misleading when applied to individual birds, particularly wild birds as some wild species lose their specific antibody within a month after infection.

Control. Poultry can be protected by two different strategies: eradication of the virulent virus, as practised in the United States and Australia (Walker, Heron and Mixson, 1973); or immunization of chickens to make them resistant to the virus (Allan and Dawson, 1973). While eradication is less costly in the long run, it requires a well-developed veterinary service organization that can respond quickly, and a government that is committed to using this approach and to funding it, prerequisites which may not exist in many countries.

Vaccination can be practised without or within a national programme. However, it is important that the government provide a reliable diagnostic service and maintain quality control over the production of vaccine. A successful vaccination programme is very dependent upon potent, high-titred vaccine that is free of hazardous impurities (Allan, Lancaster and Toth, 1973; Hitchner, 1976).

Several kinds of vaccines are produced for use in combating Newcastle disease and applied by several routes using different time schedules. Virus strains of any level of virulence may be inactivated by chemicals such as formalin, betaproprolactone or ethelinamine, and used with alumina hydroxide or with oil adjuvant; these are usually administered intramuscularly. Avirulent strains of the lentogenic type are administered directly by eyedrop or intranasally, or may be given in drinking water or as an aerosol. Mass vaccination in drinking water or by spray has two advantages over other procedures: individual chickens need not be handled and therefore are not disturbed or injured; and less labour is required. The disadvantages lie primarily in opportunities for undervaccinating the population if the procedure is not properly carried out, and for inadvertently augmenting any underlying respiratory disease.

Irrespective of the vaccine employed, in areas of high exposure it is most important that birds be revaccinated at appropriate intervals to maintain a good immunity. Some authorities have recommended a 4-4-4 programme: vaccination at four days, four weeks and four months. Others in areas in which the risk is very high have recommended revaccinating as often as every six weeks. In some large integrated poultry enterprises revaccination is carried out whenever the mean serologic titre on a sample of birds falls below a prescribed threshold (i.e., an HI titre of 1-160).

Even in areas of high risk, adult

FIGURE 2. Inoculation of embryonating egg

Photo: University of Wisconsin

TABLE 1. **Pathotypes of Newcastle disease** (all data for adult chickens)

	Signs	Gross lesions	Survival time	Percent survival
Doyle's disease (peracute)	Facial oedema, haemorrhage of lower eyelid, nasal discharge, diarrhoea, prostration	Haemorrhages in trachea & larynx and gut (particularly proventriculus & caecal tonsil)	4-8 days	0-19
Beach's disease (respiratory-nervous	Laboured breathing and nasal discharge, tremor, paralysis and torticollis	Air sac thickening, haemorrhages rare	8-12 days	10-80
Beaudette's disease (respiratory)	Mild respiratory signs, decreased appetite, decreased lay	Unremarkable		[1] 100
Hitchner's disease (unapparent)	None [2]	None [3]	—	100

[1] Mortality in young chicks ranges from 5 to 20%. — [2] May increase signs of concurrent infection. — [3] Patching necrosis and inflammation of tracheal epithelium are evident histologically.

TABLE 2. **Isolation of Newcastle disease virus**

Host system	Isolates from diseased birds	Isolates from unapparent infections
Chicken embryo 10 days old, inoculated allantoically	Haemagglutinins produced in 48-72 hours	Haemagglutinins produced in 48-72 hours
	Embryos killed in 44 to 99 hours	Embryos survive 96-120 hours or longer
Monolayer of chicken embryo fibroblasts: (with Mg & DEAE [1] in overlay)	Plaques of one or more types and sizes	Microplaques
(without Mg + DEAE [1] in overlay)	Plaques of one or more types and sizes	No plaques

[1] DEAE - diethylaminoethyl ether.

chickens on a good vaccination programme can be maintained free of clinical infection. Rearing younger birds and raising broilers in such areas are difficult even when vaccination is carefully carried out and sanitary practices are observed. Chicks less than six weeks of age are not as responsive to antigens as older chickens and, if passive antibodies are present during the first three weeks of life (as would be expected in such an area), they are even less likely to develop satisfactory antibodies. The only course is to isolate the growing chicks from older birds and to vaccinate them frequently enough to provide a good measure of protection to all except the few unresponsive individuals.

Control of Newcastle disease is possible whenever the poultry owner practises sanitation commensurate with his risk and vaccinates his flocks regularly and properly, and where the government prevents the spread of new strains through appropriate actions and ensures the availability of potent and safe vaccines through regulation. ■

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The Canchim breed of Brazil

A. Teixeira Vianna and R. Jondet

Introduction. The history of the Canchim breed dates back to 1940, when, under the direction and guidance of Teixeira Vianna and with assistance from M. Santiago, the experimental breeding station of São Carlos in the State of São Paulo was established by the Ministry of Agriculture on the former Canchim ranch (Teixeira Vianna *et al.*, 1962). It now has over 3 000 ha of land and is incorporated into the statewide research unit (UEPAE).

The ranch has a relatively temperate climate with an average temperature below 22°C during the hot months and above 16°C during the coolest months. The highest temperatures are attained in January and the lowest in June; if the temperature occasionally rises to 32°C during the summer, the nights are nonetheless usually cool and pleasant. The grasslands of the Canchim ranch consist of *Panicum maximum*, *Melinis multiflora* and *Hyparrhenia rufa*. The basic cattle originally consisted of Indobrasil zebu, the result of mixing the principal Indo-Brazilian breeds (mainly Gir, Guzerat and Nellore) between 1920 and 1930. The characteristics of the Indobrasil are a moderately convex profile, a coat usually white or grey in colour (yellow or solid red are tolerated), long ears and a fairly well-developed hump and dewlap. Females weigh an average of 354 kg at 2 years. The original number of cows which produced the halfbred foundation animals was 368 (292 Indobrasil, 44 Guzerat and 32 Nellore).

The French Charolais breed was used for crossing with the basic Indobrasil cattle. Among European breeds noted for beef production, the Charolais appeared to adapt very well to the natural conditions of central Brazil. The Charolais stock used in the formation of the Canchim breed originated from a group of cattle sent to Brazil from France in 1922 on the occasion of an exhibition organized as part of the celebration of the Independence Centennial. Shortly after their arrival they were transferred to the State of Goias, where they remained until 1936 when they and their progeny were sent to Canchim.

The Canchim breed is the result of a judicious admixture of animals with different proportions of Indobrasil-zebu and Charolais blood in the search for maximum heterosis as manifested in greater hardiness, robustness and productivity.

DEVELOPMENT

The programme of work involved a 20-year period of Charolais-zebu crossing in all its forms and with different proportions of blood (1/2 Charolais-zebu, 1/2 zebu-Charolais, 3/4 Charolais-zebu, 3/4 zebu-Charolais, 5/8 Charolais-zebu, 5/8 zebu-Charolais), as well as the observation of the breeding and growing characteristics of the different crosses (feeding, behaviour, resistance to climate and diseases, reproductive aptitudes, weight at various ages, rate of growth, etc.). Females were kept on pasture throughout the year without any supplementary feeding, except for a weekly addition of a mineral mixture distributed in the corrals. Charolais bulls received a supplementary ration to prepare them for the breeding period, during which their diet was the same as that of the cows. Zebu and Charolais-zebu crossbred bulls were maintained exclusively on pasture, apart from the weekly mineral mixture.

From the health point of view the animals were at all times under strict

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A Canchim bull. Age, 2 years 8 months; weight 710 kilograms

control; warble flies were sought out and eliminated every fifteen days, as also were ticks, destroyed by means of appropriate dips. Calves were systematically inoculated against pneumoenteritis. Every six months they were tested for tuberculosis and vaccinated against foot-and-mouth disease; blood samples were taken for brucellosis testing. Those animals showing a positive reaction to *Brucella* were destroyed.

The first halfbreds, showing good uniformity, were born in 1941. They showed good slaughter qualities and precocity, which they owed to the Charolais parent. Their high digestive capacity allowed them to adapt well to tropical pastures, and they developed rapidly and clearly showed their potential for beef production; at 18 months both males and females exceeded 300 kg. Their coat was generally straw-coloured. They had an improved rib cage and depth, compared wtih the pure zebu, and a straight dorsal profile. Their zebu inheritance made tham active animals and provided tham with: an elastic skin that handled well; a greater resistance to heat, ticks, warble flies and other ectoparasites; a better capacity to make good use of rough fodder; a lively gait; and a well-developed herd instinct. They were able to traverse long distances in search of feed and as a result yielded a good return at slaughter even in the dry season (an average carcass weight of 59 percent for males between 20 and 30 months weighing 450 kg). Halfbred Charolais-zebu cows weighed on average 590 kg and were found to be good mothers, their milk being more than adequate for the calves. Their udders were well shaped and, in 80 percent of the cases, the teats were well set, without being excessively large as is the case with purebred zebu cows.

The 3/4 Charolais-zebu animals, the first of which were born in 1946, were the offspring of halfbred cows by Charolais bulls. They were less hardy and adapted less well to tropical conditions than the halfbreds. They were also more susceptible to ectoparasites, thus requiring more frequent treatment. They were not as active as the halfbreds, the 3/4 zebu-Charolais and the 5/8 Charolais-zebu. At 24 months of age, 3/4 Charolais-zebu males attained a mean weight of 472 kg and females 333 kg; cows weighed an average of 580 kg at 3-4 years. The latter were used to produce 5/8 zebu-Charolais calves by mating to purebred zebu bulls, but this part of the crossbreeding programme had to be abandoned later when it was found that the 5/8 zebu-Charolais progeny were of little interest.

Threequarter-bred zebu-Charolais are the result of matings between halfbred cows and zebu bulls. They are very hardy like the pure zebu, but conformation and precocity are superior. The females reached an average weight of 369 kg at 24 months and proved to be excellent mothers

TABLE 1. **Average weight of purebred Charolais and halfbred Charolais-zebu (Indobrasil) males raised exclusively on pasture**

Breed/Type	Birth		6 months		12 months		18 months		24 months	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
		Kg		*Kg*		*Kg*		*Kg*		*Kg*
Pure Charolais	290	39.3	208	176.8	175	299.2	137	383.5	112	488.6
½ Charolais-zebu	293	30.4	278	174.0	234	248.2	112	303.2	57	366.0
3/4 Charolais-zebu	92	37.5	81	214.5	70	285.2	50	391.1	19	472.7
3/4 zebu-Charolais	315	37.2	282	200.3	203	282.3	44	354.6	3	433.0
5/8 Charolais-zebu	148	34.4	96	189.5	93	273.7	72	382.6	64	434.3
5/8 zebu-Charolais	101	35.9	85	182.7	83	263.1	30	396.3	19	418.9
5/8 zebu-Charolais mated *inter se:*	28	34.6	27	152.4	8	286.4	—	—	—	—
5/8 Charolais-zebu (Canchim) mated *inter se:*	45	36.8	21	204.0	16	277.3	13	386.8	13	444.5

for their 5/8 Charolais-zebu offspring.

The 5/8 Charolais-zebu came into being in 1949 as a result of mating purebred Charolais bulls to 3/4 zebu-1/4 Charolais cows that weighed approximately 580 kg at 3-4 years. These animals appeared to be best able to combine the desirable qualities of both breeds: the precocity and conformation of the Charolais, and the hardiness of the zebu. They have a characteristic slaughter conformation with a broad and deep chest, well-arched and well-spaced ribs, and relatively short, well-muscled quarters with a good stand. Steers can easily weigh 380 kg at 18 months and often 450 kg, like the 3/4 Charolais-zebu. They are particularly resistant to ectoparasites and heat. The male has a small cervical hump, smaller than that of the zebu, a characteristic not present in the female. Its head is rather smaller than that of the Charolais, with horns pointed outward, forward or upward. Its drooping ears are rather small, half way between those of the two breeds. The coat is straw-coloured, with tinges of yellow, red, grey or white. The skin is supple, handles well and is dark, serving as an excellent protection against the sun. The hair is thick up to 8-10 months of age and becomes shorter and thicker as the animal grows older, thus giving its body a protective coating of a light colour which reflects solar radiation well. The mucosa are pigmented, dark or light, with no sign of erythema caused by sunlight. The udder is well shaped and well hung with equally well-shaped teats. The cows have a nervous temperament and a highly developed maternal and herd instinct, which facilitates their handling at pasture. These 5/8 Charolais-zebu crossbreds do well during the dry season, which in Brazil runs from April to September.

The 5/8 zebu-Charolais are the offspring of 3/4 Charolais-1/4 zebu females mated to purebred zebu bulls. On average the cows weigh 570 kg at 3-4 years. Their characters are very similar to those of the zebu in all respects, although there is a greater amount of genetic segregation compared with the 5/8 Charolais-zebu crossbreds. There is therefore a higher percentage of individuals with a darkish coloration which is not desirable in the tropics.

The best 5/8 Charolais-zebu and 5/8 zebu-Charolais respectively were each mated *inter se* and the performance of the two types compared. The results soon demonstrated the superiority of the 5/8 Charolais-zebu crosses.

The animals that constitute the Canchim breed are the result of *inter se* matings of the 5/8 Charolais-zebus that were born in 1952-53. They are well-developed animals, with an excellent slaughter conformation. Some weigh 400 kg at 18 months, and most exceed 420 kg at 24 months; their precocity is similar to that of the 5/8 Charolais-zebu crossbreds. Their coat is straw-coloured in about 75 percent of the animals; it is more or less a light yellow in approximately 20 percent, while the remaining 5 percent have different tints of grey, red or mixed coloration. As a rule the coat tends to become lighter as the animals get older. The hair is short and shiny, and the mucous membranes are usually dark, except in 25 percent of the animals in which they are light. The horns are usually of a colour matching the mucosa, while the skin is supple and dark like the mucosa; the horns are like those of the Charolais but smaller. These animals make the best of the natural resources and do very well when maintained exclusively on pasture; they have a good resistance to heat and ectoparasites.

The 5/8 zebu-Charolais mated *inter se* have not been satisfactory. Too great a dissociation among traits was observed, which accented once again the irregular results obtained in the appearance and performance of the 5/8 zebu-Charolais animals.

The crossbreeding programme that

TABLE 2. **Average weight of purebred Charolais and halfbred Charolais-zebu (Indobrasil) females raised exclusively on pasture**

Breed/Type	Birth		6 months		12 months		18 months		24 months	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight	Number	Weight
		Kg		*Kg*		*Kg*		*Kg*		*Kg*
Pure Charolais	281	36.7	225	166.0	206	272.0	185	337.8	176	408.8
½ Charolais-zebu	277	30.5	268	164.5	255	238.1	257	312.5	257	376.6
3/4 Charolais-zebu	98	35.4	91	196.1	82	249.9	79	311.5	77	333.0
3/4 zebu-Charolais	333	33.2	305	181.2	282	246.7	270	324.2	254	369.1
5/8 Charolais-zebu	161	33.3	123	182.5	118	259.5	101	333.5	99	385.2
5/8 zebu-Charolais	111	32.7	103	169.9	92	237.9	74	327.4	73	362.7
5/8 zebu-Charolais mated *inter se:*	23	33.6	17	151.4	10	241.8	10	305.4	—	—
5/8 Charolais-zebu (Canchim) mated *inter se:*	42	34.2	18	176.0	16	238.4	16	318.9	16	375.6

was pursued may be summed up in the following manner:

1st generation:
$C \times Z = \frac{1}{2} C \frac{1}{2} Z$
2nd generation:
$Z \times (\frac{1}{2} C \frac{1}{2} Z) = 3/4\ Z\ 1/4\ C$
3rd generation:
$C \times (3/4\ Z\ 1/4\ C) = 5/8\ C\ 3/8\ Z$
4th generation:
$(5/8\ C\ 3/8\ Z) \times (5/8\ C\ 3/8\ Z) = 5/8\ C\ 3/8\ Z.$

The crossbreds mated *inter se* thus obtained possessed 62.5 percent Charolais and 37.5 percent zebu inheritance. Weights at birth and at 6, 12, 18 and 24 months of age of the Canchim and other crossbreds are given in Table 1 for males, and in Table 2 for females.

VALUE AND QUALITY

With successive generations the breed type has become progressively more stable, and the number of undesirable offspring has never exceeded 10 percent. Calves are especially resistant to diseases (particularly pneumoenteritis), and mortality seldom exceeds 5 percent.

Canchim animals have a lively temperament. They thrive on natural pastures and easily withstand the often adverse conditions of tropical climates. In this respect they are on a par with purebred zebus, but they excel the latter in precocity and yield. Canchim cattle are thus a happy association of the advantages of the zebu (rusticity and adaptability to tropical conditions) and those of the Charolais (precocity and high yield of good quality meat). As Alves Santiago (1970) reports, they are the result of one of the best crossbreeding experiments made in Brazil.

Fertility. Fertility is influenced by numerous factors or groups of factors, such as nutrition, climate management and pathological factors. It is an essential element that must be considered of paramount importance when studying the productivity of any breed. The relationship between a given number of cows and the number of viable calves that they bear is one of the most important indices of successful stock raising in general, and of beef cattle production in particular.

Canchim heifers are mated when they attain a liveweight corresponding to 60 percent of the average weight of adult cows, i.e., when they weigh 360 kg at the age of 22 to 27 months. The resulting calves are run on pasture with their dams; they are weaned and branded at 8 months.

The results shown in Tables 3 and 4 provide information on the fertility of 1 552 cows containing different percentages of genes from the parental breeds. With regard to the Charolais cows included in the analysis (either imported or born in Brazil), mating means hand mating by natural service. In the case of cows of other breeds or Charolais-zebu females, the same term means "exposed to the bull" at pasture, at the rate of one bull per 40-50 cows. Mating is programmed to take place during the months of August to October, so that calving occurs during the dry season (April to September). This avoids diseases — especially pneumoenteritis — to the maximum possible extent and results in the least possible loss of calves. Table 3 also deals with 939 cows of various breed combinations served by purebred Charolais bulls.

It was found that fertility in the purebred Charolais is not very high under the tropical conditions prevailing, irrespective of whether the animals are imported or born in Brazil (the number of services per conception for the two groups was 3.2 and 3.5 and the reproductive index [live calves born per cow mated] 27.8 and 24.8 percent respectively). Fertility

increases when Charolais bulls are mated to zebu cows of the Indobrasil and Nellore breeds (number of services: 2.3 and 2.2; reproductive index: 42.0 and 45.3 percent respectively). On the other hand, the results obtained with Guzerat cows are only slightly different from those obtained with Charolais females (3.1 services per conception and a reproductive index of 31.2 percent). In crossbred cows fertility is associated with the proportion of zebu blood. Thus, in halfbred and 3/4-bred Charolais-Indobrasil cows the numbers of services per conception are 1.5 and 1.6 respectively, and the corresponding reproductive indices are 64.8 and 60.9 percent. Table 4 gives the results of matings by zebu bulls with 613 cows of varying degrees of crossbreeding, The number of services per conception lies between 1.3 and 1.7 and reproductive indices never fall below 54 percent. It is observed that the best results (1.3 matings per conception, 79.4 percent fetility rate and 69.8 percent reproductive index) are obtained through reproduction within 5/8 Charolais-zebu mated *inter se*, i.e., animals of the Canchim breed.

Table 5 shows the results of programmes in purebred Charolais females (imported or born in Brazil), crossbred Charolais-zebu females (Indobrasil, Nellore, Guzerat), and Canchim females. The ratio of normal calvings to the number of conceptions is highest among the Charolais-Nellore halfbreds (100 percent), followed in descending order by 1/2 Charolais-Indobrasil (97.2 percent), 5/8 Charolais-Indobrasil (96.2 percent), 3/4 Charolais-zebu (94.1 percent), Canchim (88.0 percent), and imported and Brazilian Charolais (87.6 and 86.6 percent).

Abortions are between 3.0 and 4.9 percent of gestations among the 5/8 Charolais-zebu, Canchim and the 3/4 Charolais-zebu. These are higher than among the Charolais-Nellore halfbreds, Guzerat and Indobrasil (0 to 2 percent), but only half as frequent as among purebred Charolais (9.3 and 9.7 percent). The incidence of stillbirths is higher among Canchim cows (8 percent) than among cows of all other breeds including the Charolais (0 to 4 percent). Fortunately, it seems that these figures, which involve only 40 Canchim females, are not always the rule, as shown by the results of a more recent study made by E.A. Beolchi (1977 — unpublished personal communication) at the São Jorge ranch (Cedral, State of São Paulo) over a period of 10 years (1965-75). This study covers 115 females, of which 32 are 3/4 zebu-Charolais crossbreds and 83 are Canchim. All were served at the age of 22 months when weighing some 400 kg; seven were destroyed afterwards because their calving period exceeded 15 months. Stud bulls received a daily ration of concentrates with additions of mineral salts and bone meal. In a total of 440 normal calvings, there were 9 difficult births (2 percent) and 4 stillbirths (0.9 percent). In the case of the 83 Canchim cows, the majority of which (90.4 percent) were on the ranch between 1967 and 1971, it was observed that: age at first calving was between 28 and 38 months for 86.8 percent of the cows (average 33.3 months); the number of calves delivered per cow was 3.83; and reproductive efficiency averaged 95.9 percent, with a figure of 100 percent or higher in the case of more than half (43) of the cows studied.

TABLE 3. **Comparative fertility of Charolais, zebu and Charolais × zebu cows when mated to Charolais bulls**

Number of cows	Female breed/Type	Male breed/Type	Number of services	Number of services per conception	Fertility rate [1]	Reproductive index [2]
					. . . . *Percent*	
55	Charolais (imported)	Charolais	407	3.2	31.7	27.8
184	Charolais (Brazilian)	Charolais	1 802	3.5	28.6	24.8
292	Indobrasil	Charolais	1 171	2.3	43.2	42.0
32	Nellore	Charolais	128	2.2	45.3	45.3
44	Guzerat	Charolais	77	3.1	32.5	31.2
168	1/2 Charolais-zebu [3]	Charolais	298	1.5	68.8	64.8
164	3/4 Charolais-zebu [3]	Charolais	417	1.6	63.3	60.9

[1] Includes viable births, stillbirths and abortions. — [2] Includes only viable births. — [3] Indobrasil breed.

TABLE 4. **Comparative fertility of Charolais × zebu cows when mated to zebu or Charolais × zebu bulls**

Number of cows	Female breed/Type	Male breed/Type	Number of services	Number of services per conception	Fertility rate [1]	Reproductive index [2]
					. . . *Percent* . . .	
201	1/2 Charolais-zebu [3]	Indobrasil	451	1.4	73.9	68.7
40	3/4 Charolais-zebu [3]	Indobrasil	59	1.5	66.1	57.6
200	1/2 Charolais-zebu [3]	Guzerat	476	1.7	58.0	54.2
74	3/4 Charolais-zebu [3]	Guzerat	140	1.3	77.9	75.7
40	5/8 Charolais-zebu [3]	5/8 Charolais-zebu [3]	63	1.3	79.4	69.8
58	5/8 zebu-Charolais [3]	5/8 zebu-Charolais [3]	76	1.4	72.4	64.5

[1] Includes viable births, stillbirths and abortions. — [2] Includes only viable births. — [3] Indobrasil breed.

FLESHING CAPACITY

During the 20 years of formation of the Canchim herd the animals were weighed monthly up to the age of

TABLE 5. **Reproductive efficiency of purebred Charolais and various crossbred Charolais-zebu females**

Breed/Type	Number of cows	Number of recorded gestations	Normal births		Abortions		Stillbirths	
			Number	%	Number	%	Number	%
Imported Charolais	55	129	113	87.6	12	9.3	4	3.1
Brazilian Charolais	184	515	447	86.6	50	9.7	18	3.5
½ Charolais-zebu Indobrasil	292	506	492	97.2	10	2.0	4	0.8
½ Charolais-zebu Nellore	32	58	58	100.0	0	0.0	0	0.0
½ Charolais-zebu Guzerat	44	25	24	96.0	0	0.0	1	4.0
3/4 Charolais-zebu [1]	168	205	193	94.1	10	4.9	2	0.9
5/8 Charolais-zebu [1]	164	264	254	96.2	8	3.0	2	0.8
5/8 Charolais-zebu [1] (Canchim) mated *inter se:*	40	50	44	88.0	2	4.0	4	8.0

[1] Indobrasil breed.

TABLE 6. **Growth rate of purebred Charolais and various Charolais-zebu (Indobrasil) crosses up to 24 months of age**

Breed/Type	Males		Females	
	Number	Average daily gain	Number	Average daily gain
		Grams		*Grams*
Purebred Charolais	112	615	176	509
½ Charolais-zebu	57	459	257	474
3/4 Charolais-zebu	19	596	77	407
3/4 zebu-Charolais	3	542	254	460
5/8 Charolais-zebu	64	547	99	482
5/8 zebu-Charolais	19	524	73	452
5/8 Charolais-zebu (Canchim) mated *inter se:*	13	558	16	467

TABLE 7. **Comparative weight gains over 140 days in different breeds of zebu and Canchim cattle**

Breed	Number	Weight gain per animal	Average daily gain
		Kilograms	
Canchim	10	142	1.014
Guzerat	28	108	0.757
Tabapua	9	100	0.714
Nellore	128	99	0.707
Polled Nellore	17	84	0.600
Gir	20	83	0.592

calving ($2\frac{1}{2}$ years) in the case of females and to the age of 4 years in the case of males.

Weight for age. Weight at birth of Canchim calves is generally between 34 and 40 kg; Tables 1 and 2 show average weights of 36.8 kg for males and 34.2 kg for females. These weights are slightly lower than those of the various intermediate crossbreds but are in fact rather close to those of the purebred Charolais (males 39.3 kg, females 36.7 kg). They are clearly higher than those of the four main zebu breeds in Brazil which average 28.2 kg for males and 26.5 kg for females. Moreover, it seems that the weight at birth of Canchim calves tends to increase each year as management conditions improve. At the age of 6 months males weigh 204 kg, and females 176 kg. They are weaned at 7-8 months, weighing an average of 212 kg for males (some weigh up to 230 kg) and 194 kg for females. Weights of 445 kg at 2 years of age (Table 1) and over 700 kg at 32 months are observed, with only pasture feed and no supplement of concentrates (at most, a mineral supplement is provided).

These results bring out the high feed conversion potentials of Canchim cattle which, in several Brazilian states, make them preferable to Charolais purebreds.

Growth rate. Weight gain between the age of weaning and 18 months is a valued characteristic at the Canchim ranch. It is believed in fact that it is during this period that the individual shows best its potential features. On the basis of the liveweight data collected, animals are classified into four groups: outstanding (élite), superior, average and inferior. Animals in the last group are sent to slaughter, those in the "average" category and some in the "superior" category are sold at auction to cattle raisers for breeding purposes; the "outstanding" animals are kept for use at the Canchim ranch.

The figures in Table 6 show the growth rates of the different Charolais-zebu crossbreds and demonstrate that Canchim cattle give satisfactory

rates in both males, with an average daily gain of 558 g, and females, with 467 g. These figures are slightly below those for purebred Charolais but greatly exceed the average daily gains recorded for the main Brazilian zebu breed, the Indobrasil, which were 372 g and 367 g respectively.

A statistical analysis of results has yielded the following conclusions on rates of growth. Among males there is no significant difference between purebred Charolais, 5/8 Charolais-zebu and 5/8 zebu-Charolais; however, all these groups are significantly better than the Charolais-zebu halfbreds. Among females there is no significant difference between the various crossbreds, although purebred Charolais have a significantly higher rate of liveweight gain than the 3/4 Charolais-zebu.

In the control experiments on individual weight gains carried out in the State of São Paulo no other breeds could equal the performance of Canchim cattle. These tests compared young bulls of different breeds between 9 and 13 months of age for a period of 140 days. During that period all the animals received the same feed and were maintained in a feedlot with no access to pasture. At the end of the test the weight gain of each bull was calculated. This character was found to be highly heritable (Teixeira Vianna, 1970), and males making rapid weight gains were therefore set aside for breeding. Young Canchim bulls commonly showed weight gains of 136 to 140 kg during the 140-day test. In certain cases a daily gain of up to 1 700 g was recorded.

Similarly, in a test made at Sertãozinho (State of São Paulo) in 1975, 212 animals of various zebu breeds were compared simultaneously with 10 Canchim animals. The figures in Table 7 demonstrate the superiority of the Canchim, which showed a daily weight gain of 1 014 g, followed by Guzerat with 757 g.

Comparative weights. With fattened oxen, among bullocks of the same breed at 18 months, weights were around 450 kg with a carcass yield of over 57 percent; others raised on pasture, with a concentrate feed supplement during the last 4 months, reached an average weight of 486 kg at 15 months, with 284-kg carcasses (i.e., a yield of 58.4 percent); while a group of five 15-month-old 5/8 Charolais-zebu reached an average weight of 436 kg and a carcass yield of 62.4 percent.

TABLE 8. **Baby beef production from Canchim steers (São Jorge, Cedral, State of São Paulo)**

Animal lots (30-50 per lot)	Average initial weight (14-15 months)	Average final weight (after 105 days)	Average weight gain/head in 105 days	Average daily gain/head
		Kilograms		
A	301	435	134	1.276
B	310	430	120	1.142
C	306	422	116	1.104
D	312	444	132	1.257
E	309	426	117	1.114
F	310	435	125	1.190
G	310	435	125	1.190
H	312	428	116	1.104
I	310	430	120	1.142
J	313	458	145	1.380
K	315	444	129	1.228
L	318	446	128	1.219
M	316	445	129	1.228
N	304	416	112	1.066
O	319	453	134	1.276
P	318	446	128	1.219
Mean	311.4	437.0	125.6	1.196

Source: E.A. Beolchi (1977 - personal communication).

Yield of baby beef. The Canchim breed is particularly suited to the production of high-quality baby beef (E.A. Beolchi, 1977, personal communication). Young bulls intended for baby beef production are rounded up at the age of 13 to 15 months and penned in herds of 36 to 50 individuals on an area of 1 000 m^2, of which 200 m^2 are covered. They receive a daily ration of concentrate feed consisting of corncob meal, cottonseed cake and molasses; this is supplemented with 15 kg of green fodder per head. Water is made available *ad libitum*. The animals are also given mineral salts and bone meal. This feeding regime lasts 105 days, so that it is possible to run three such operations every year.

Table 8 summarizes the results reported from 16 lots of animals (36 to 50 per lot) between 1970 and 1975. It can be seen that after entering the baby beef production programme at an age of some 15 months with an average weight of 311 kg, the animals are finished at about 19 months of age with an average weight of 437 kg, i.e., a total gain of almost 126 kg and a daily increase of 1 196 g. The yield of high-quality baby beef per head is on average 236 kg.

Milk yield. Excellent as they are as beef animals, Canchim cattle are no less interesting with regard to milk production; the breed can be considered a dual-purpose one, at least in tropical regions. [Canchim

females are good mothers and good milch cows; under extensive conditions on pasture and with a daily supplement of sugarcane, cottonseed cake and minerals, they yield 8-10 litres of milk per day.

DISTRIBUTION AND IMPACT

At the beginning, the Canchim ranch sold mainly the males, but after 1968 it also marketed females at periodic auctions. In addition, pilot herds, each consisting of a dozen cows and one or two bulls, were placed in several stations belonging to the Ministry of Agriculture in order to make a close study of their behaviour at different latitudes.

The Canchim breed was officially recognized by the Brazilian authorities on 11 November 1972. With this came about the creation of the Brazilian Association of Canchim Cattle Breeders[1], which has already registered more than 30 000 individuals in its herdbook in which they are at the sixth generation. The association now has 83 members, 48 of whom are in the State of São Paulo, 12 in the State of Goias, 10 in the State of Paraná, 8 in the State of Rio Grande do Sul, and one each in the States of Bahia, Paraiba, Minas Gerais and Mato Grosso. In the centre of the Mato Grosso, Canchim cattle raised under the same conditions as the local cattle produce calves that weigh between 40 and 50 kg at birth. The results obtained on the Marajo Island (State of Pará) with Canchim bulls open up new and promising horizons as indicated by Teixeira Vianna (1970). Finally, observations made in recent times in several breeding ranches in the State of São Paulo demonstrate that the offspring from crossing zebu cows with Canchim bulls weigh 15-30 kg more at 2 years of age than purebred zebus.

These results serve to demonstrate the innate potential of Canchim animals, a potential that has been established as a result of a sustained effort over many years at the São Carlos Experimental Station.

Canchim steers raised exclusively on pasture

SUMMARY

The Brazilian Canchim breed of cattle is the result of a combination of zebu (Indobrasil) and Charolais stock. The animals (5/8 Charolais-zebu bred *inter se*) show high fertility and fecundity. They are hardy animals, and this trait allows them to withstand with ease the rigours of tropical climates (heat, solar radiation and attacks from ectoparasites, particularly the vectors of piroplasmosis). Males weigh 500 kg at two years, and more than 700 kg at 32 months. Average weight gain of animals under fattening often exceeds 1 kg a day and carcass yield at slaughter may reach and even surpass 62 percent. In ranches producing baby beef, steers slaughtered at 17-19 months weigh an average of 437 kg, i.e., produce 236 kg of meat, through an average daily gain of nearly 1 200 g. The females are good milch cows and produce up to 10 litres of milk daily.

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[1] "Associaçao Brasileira dos Criadores de Bovinos de Raça Canchim" (ABCBRC). Business address: Parque Agua Branca, 455, Avenida Francisco Matarazzo, São Paulo, Brazil.

Second FAO expert consultation on research on tick-borne diseases and their vectors

This consultation, held in Rome from 12 to 16 December 1977, was attended by fifteen experts and six observers from twelve different countries and three international organizations (ILRAD, OIE and WHO), as well as by FAO staff from field projects concerned with the subject.

The consultation reviewed FAO's current programme on ticks and tick-borne diseases and recent world research on tick-borne diseases, particularly tropical theileriasis, heartwater and East Coast fever and their vectors. A series of important proposals were made in order to guide FAO and other institutions, both national and international, in their efforts to control ticks and tick-borne diseases.

The consultation recommended that FAO should:

- consider the control of ticks and tick-borne diseases as a separate programme element with steadily increasing funding, particularly for additional outposted officers in Latin America, the Near East, and Asia and the Far East;
- promote research on *Theileria annulata* (in particular, comparison of current immunization methods, improvement in methods of vaccine production and distribution, and study of the epidemiology of the disease);
- stimulate further work on *Cowdria ruminantium*, the causal organism of heartwater, with special reference to epidemiology, serology and immunization;
- encourage the immediate application of the infection and treatment method for immunization of valuable animals against East Coast fever and stimulate research to develop alternative methods;
- take immediate steps to reduce the high level of cattle wastage caused by the introduction of susceptible exotic stock into tropical countries without due consideration of their susceptibility to tick-borne diseases;
- seek ways and means of stimulating research on the biology and ecology of important tick species, particularly in Africa, Asia, Central and South America;
- urgently explore the possibility of obtaining funds for the location of interim staff to continue the development of the FAO acaricide resistance test kit at CSIRO in Australia and continue negotiations to establish the World Acaricide Resistance Reference Centre;
- proceed immediately with the preparation of the practical field manual on the control of ticks and tick-borne diseases of cattle and obtain the additional funds required for its publication from extra-budgetary sources; and
- initiate practical training courses for dip vat managers and their supervisors in Africa, Latin America, the Near East and Asia.

The full report of the consultation will be published later this year.

Postgraduate course in Food Hygiene and Veterinary Public Health

The eighth in the series of postgraduate courses in Food Hygiene and Veterinary Public Health organized under the FAO/DANIDA [1] Cooperative Programme will be conducted at the Royal Veterinary and Agricultural University, Copenhagen, Denmark, from 1 September 1978 to 30 June 1979. The object of the course is to provide advanced training in the principal subjects from which the course derives its title, with special emphasis on animal products, meat handling and meat hygiene, and the educational aspects of these subjects. The award of a Diploma of Food Hygiene and Veterinary Public Health may be made by the University to candidates who successfully complete the course.

Participants in the course are selected from among candidates nominated by governments at the invitation of FAO. Admission requirements include a degree from a university or college equivalent to at least the B.V.Sc. The candidates should preferably be teachers or research workers in the subjects covered by the course and should have an adequate knowledge of English to benefit from it.

The training programme includes lectures, seminars, colloquia, practical laboratory training, field excursions and individual research on a subject approved by the Faculty and relevant to conditions in the candidate's home country. The Director of the course, which is administered by the Veterinary Faculty for FAO Fellows at the Royal Veterinary and Agricultural University, Copenhagen, is Professor H. Errebo Larsen of the Institute of Veterinary Microbiology and Hygiene of the University.

Further information concerning the course may be obtained from Dr. N-I. Heje, Coordinator, Secretary to the Veterinary Faculty for FAO Fellows, Bülowsvej 13, DK 1870 Copenhagen V, Denmark.

[1] Danish International Development Agency.

FAO/Netherlands expert consultation on national coordinating organizations and institutions for dairy development

This consultation was held at the International Agricultural Centre, Wageningen, Netherlands, from 6 to 16 December 1977, with support from the Royal Netherlands Dairy Federation on the occasion of its seventy-fifth anniversary.

The consultation was attended by experts from 18 developing and 9 developed countries and by observers from the International Dairy Federation. Case studies prepared by the participants presented the historical background and the structure, functions and performance of the organizations and institutions concerned with the coordination of national dairy development in the respective countries. These were discussed in detail in three working groups and reported on at a joint session of all participants. The more important recommendations

resulting from the consultation were:

- that governments should create an institutional structure for national dairy development, planning and coordination, which ensures participation of farmers and milk producers, processors, distributors and consumers in drawing up the plan and in implementing it through cooperatives, associations and related local bodies;
- that the establishment and/or strengthening of farmers' organizations and, more specifically, of milk producers' cooperatives in all forms, should be encouraged;
- that depending on the stage of dairy development in the country concerned, the agreed programmes should be implemented by an executive agency (advised by a consultative council) or an autonomous coordinating institution with executive authority over dairy development, and that representatives of farmers and other groups connected with the dairy sector should be invited to participate in the decision-making processes;
- that the International Scheme for the Coordination of Dairy Development and the FAO Dairy Training Programme be given greater support by donors to promote their further activities; and
- that countries with proven experience in dairy cooperatives should be encouraged to assist others desirous of developing their dairy industries, through an exchange of staff.

A detailed report of the consultation will be published in English, French and Spanish during 1978. Summaries of the case studies presented by the participants will be attached to the report.

The outlook for meat production and trade in the Near East and east Africa

(Summarized from a joint study on the above subject by FAO and the World Bank, published in mimeograph form in two volumes in December 1977.)

The governments of the countries of the Near East and east Africa have all declared the objective of increasing meat production, Not only have living standards, and hence domestic demand for meat, been rising; these countries have become increasingly involved in the international market, either as buyers or sellers. This study seeks to determine: the probable size of the meat deficit in the Near East, where rapid increases in demand have been stimulated by oil-related growth in incomes; and the prospects of neighbouring east African meat exporting countries for penetrating this market. Production and trade prospects and problems over the years to 1985 are analysed for 18 countries in the Near East and 6 in east Africa. The meat categories dealt with are: beef and veal, sheep and goat meat, pig meat and poultry, with emphasis on the first two categories.

In about half the countries studied livestock has a significant economic role. But though policies are changing and investments in the livestock sector are increasing rapidly, most of the livestock in the Near East and east Africa is still raised in the subsistence sector using traditional methods. Livestock husbandry is rarely geared to the efficient production of meat; animal nutrition and health are poor, and meat marketing arrangements rudimentary. Expanding meat production, by adequately using traditional methods will be difficult if not impossible in many areas: over-grazing is reducing the productivity of pastures, and there is little prospect for expanding available grazing lands; population pressure is increasing the demand for arable land; and throughout most of the region water is usually in short supply, with periodic droughts. It is also generally the case that traditional methods of animal husbandry do not produce meat of a high standard.

Unless there are drastic changes in their present livestock development policies, the Near East countries' demand for meat is likely to continue rising more rapidly than their domestic production, and by 1985 their meat and livestock import requirements will be ten times as great as in 1970 (1.8 million tons). Individual countries' shares of the Near East region's imports are expected to change, with those of Iran and Iraq rising to 53 and 24 percent and Saudi Arabia's declining to 9 percent by 1985 (though in absolute terms its imports will be very large). After deduction of inter-regional supplies, in 1985 about 60 percent of the region's total meat import requirements (in carcass weight equivalent) is expected to consist of sheep and goat livestock, while nearly 19 percent is expected to be beef and veal (compared with 49 and 28 percent respectively in 1970). Live animal imports, especially sheep and goats, are expected to retain their importance in the future because present religious and taste preferences are expected to persist.

Of east Africa's projected meat surplus in 1985 (about 0.5 million metric tons), four fifths is expected to be cattle or beef, and less than 8 percent sheep and goat livestock and meat (compared with 75 and 24 percent respectively in 1970). Near East consumers generally consider beef inferior to lamb and mutton. Moreover, animal health in much of east Africa is still very poor by international standards, and both the quality and the prices of its beef exports face strong competition from other countries. Thus, without changing the composition of its exports, east Africa appears to have limited prospects for increasing its share of the Near East market. Exports of live sheep, goats and cattle from traditional east African sources (Ethiopia, the Sudan and Somalia) to the Arabian Peninsula are expected to continue. In the key Iranian and Iraqi import markets, strong competition from developed countries (primarily Oceania) and other developing countries (South America), already apparent by 1974, is likely to persist.

Livestock investment priorities obviously differ from one country to another, but four general objectives can be outlined:

- to bring stock numbers and production systems into line with the carrying capacity of rangeland and the supply of animal feeds;
- to increase the availability of feed economically (without drawing resources away from enterprises that are more profitable) while ensuring that human consumers have first claim on available supplies of foodgrains;
- to improve animal health and livestock management efficiency; and
- to ensure access to markets.

In modernizing their livestock industries the most difficult problems confronting the countries studied are those posed by shortages of skilled manpower and capital. It is only through emphasis on training that countries will be able to generate their own momentum in livestock development and make effective use of funds provided externally. ■

Anatomical jointing, tissue separation and weight recording proposed as the EEC standard method for beef

By D.R. WILLIAMS and P.L. BERGSTRÖM. Commission of the European Communities. Coordination of Agricultural Research. EUR 5720. 1977. 26 pages. Mimeographed.

The great diversity in methods of determining carcass composition that prevails at the present time makes it difficult to obtain experimental results from different institutes that are strictly comparable. The EEC Seminar held in 1975 on " Criteria and methods for assessment of carcass and meat characteristics in beef production experiments " concluded that a common international reference method of carcass dissection was necessary.

Therefore, as part of the EEC coordination of beef production research, Dr. D. R. Williams of the Meat Research Institute, Langford, U.K. and Dr. P.L. Bergström of the Research Institute for Animal Husbandry " Schoonoord ", Zeist, Netherlands, undertook the development of a standard method of anatomical jointing, tissue separation and weight recording. The method that they designed has been tested by the dissection teams at both Langford and Zeist and constitutes the subject matter of this mimeographed publication.

To facilitate universal applicability of the method, the carcass joints are defined with a maximum of anatomical lines of separation. Furthermore, in order to cater for the several different ways in which the data may be finally utilized in statistical analyses, the authors have provided agreed categories of tissues, and definitions, methods of separation and groupings of the various tissues. Specimen formats for weight recording after dissection of anatomical regions are also recommended. An appendix offers a summary of the procedures proposed for anatomical jointing.

P.M.

Cassava as animal feed

Edited by B. NESTEL and M. GRAHAM, 1977. International Development Research Centre, Box 8500, Ottawa, Canada K1G 3H9. Head Office: 60 Queen Street, Ottawa. 147 pages, tables, references. Microfiche edition $1.

This book contains the Proceedings of a Workshop held at the University of Guelph from 18 to 20 April 1977 and sponsored by the International Development Research Centre and the University of Guelph. Thirty-one participants from ten tropical and temperate countries and from two international research centres attended the meeting, where 14 papers and short reports were presented in six sessions.

The world production of cassava (105 million tons) is used for human and animal nutrition and for the industrial production of starch and its derivatives. Five million tons of dried cassava (12 million tons of fresh cassava roots) are expected to be used this year in compound animal feeds in Europe. The use of both cassava root and foliage as animal feeds in other parts of the world is increasing at a rapid rate.

The fields covered by the workshop included biochemical considerations (3 papers), use of cassava in poultry rations (2 papers) and in swine diets (2 papers), SCP production using cassava as a substrate (4 papers), whole plant utilization of cassava for animal feed (1 paper), use of cassava as a feed source for ruminants (1 paper), and processing technology in relation to feed value and utilization (1 paper).

MAIN STATEMENTS

The main statements and conclusions highlighted through the papers and the discussion may be summarized as follows.

It is obvious that cassava products can be successfully used as *substitutes for cereals* for different species of livestock in both temperate and tropical countries.

With regard to *toxicity*, a better characterization of the type of cassava with respect to its physical nature and its cyanide content is needed. The words " bitter " and " sweet " are misleading in terms of cyanide content. Differences in species' response may be significant. Hitherto, research work has essentially been carried out with small laboratory animals, and this may have only limited relevance to farm livestock. Although it is difficult to draw general conclusions, a high rate of incorporation of cassava in the diet appears to be more acceptable for broilers than layers. Supplementing cassava diets with methionine in livestock feeding serves to provide also the sulphur necessary to detoxify the cyanide radical to thiocyanate. The cyanide content of fresh cassava leaves appears to have no adverse effect on large ruminants, but this is not the case in small and young ruminants.

The physical properties of cassava-based diets are of importance in terms of palatability and feed consumption. Significant advances have been made in pelleting technology in recent years, but care needs to be exercised in terms of temperature control to prevent adulteration.

The question of *supplementing* cassava-based diets to ensure a nutrient balance appropriate to the species and class of livestock is one of fundamental importance.

Life cycle feeding using a high level of cassava in *swine rations* is possible but needs further study on reproductive performance.

Cassava starch, because of its higher amylopectin:amylose ratio than that found in maize cereal, is less readily digested by monogastrics. It is recognized as a good vehicle for promoting microbial synthesis using NPN in ruminant feeding.

There are good prospects for using both *cassava leaves and roots* in ruminant diets. There is however a great need to develop packages of recommended technology for cassava foliage production (agronomy, varieties, mechanization of planting and harvesting) for making the best use of cassava as a dual-purpose plant.

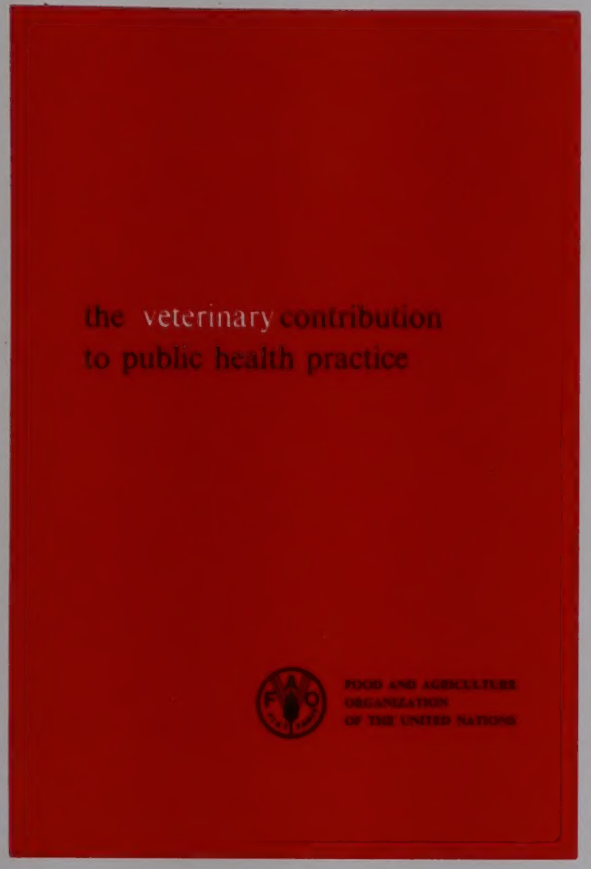
Work done in Venezuela shows that *protein* from cassava leaf meal has been produced at one fifth of the cost of protein derived from alfalfa leaf meal.

Ongoing work at CIAT with a fermentor built at the University of Guelph has revealed the great potential of cassava as a substrate for *production of* SCP. However, further research is needed with respect to the technical aspects (more particularly safety hazards) and the economic implications of this new technology before any firm recommendation can be offered.

The workshop also emphasized the tremendous potential of cassava for root and foliage production and underlined a number of research priorities relating specifically to economic development in cassava-producing countries that require solutions.

M.C.

THE VETERINARY CONTRIBUTION TO PUBLIC HEALTH SERVICE



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